

For Reference

NOT TO BE TAKEN FROM THIS ROOM

For Reference

NOT TO BE TAKEN FROM THIS ROOM

Ex libris
UNIVERSITATIS
ALBERTAENSIS



1966(F)
#158

THE UNIVERSITY OF ALBERTA

THE GENUS PELTIGERA IN ALBERTA

by

MIKE OSTAFICHUK

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF BOTANY

EDMONTON, ALBERTA

SEPTEMBER 1966

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read,
and recommend to the Faculty of Graduate Studies for
acceptance, a thesis entitled THE GENUS PELTIGERA IN
ALBERTA submitted by Mike Ostafichuk in partial ful-
filment of the requirements for the degree of Master
of Science.

ABSTRACT

This study of the lichen genus Peltigera - the first in Alberta - had two objectives. The first objective was to survey the genus in western and southern Alberta. Eight species were found to occur in the study area: Peltigera apthosa, P. canina, P. evansiana, P. horizontalis, P. malacea, P. polydactyla, P. pulverulenta and P. venosa. Many of these species are variable containing varieties and forms whose identification presents difficulties. Three other species are of doubtful or uncertain occurrence. Peltigera membranacea had been reported from this region but these reports were found to be based on incorrect identification. Peltigera lepidophora was represented by one herbarium collection so poor that its identity could not be verified. Peltigera scutata was reported by Thomson (1950) but I have seen no collections. None of these species was found in the study area. Peltigera pulverulenta is reported for the first time from Alberta and several features for distinguishing this species from Peltigera canina are discussed.

The second objective was to design techniques suitable for analyzing as many morphological features as possible and relating them to the environment. Peltigera canina was selected for this study because it is a common, highly variable and imperfectly understood species. Twelve features, chosen to represent as many aspects of the lichen and its environment as feasible, were scored to obtain numerical values. Data from representative specimens were plotted using a polygonal graph method. The results indicate that this method is a valuable tool in assessing the variability of taxonomic characters of the lichen thallus. At the same time, it provides a means of correlating structural features and environmental factors. In the case of Peltigera canina, the results

indicate that the Peltigera canina varieties canina, rufescens and spongiosa do not constitute distinct taxa, and that the thallus structure is modified by various habitat factors such as substrate.

It is considered that use of the polygonal graph method would result in simplifying classification of the genus Peltigera through better species definition.

ACKNOWLEDGMENTS

I am sincerely grateful to Dr. L. L. Kennedy for her assistance throughout the course of this study and especially for her unstinting help in preparing this manuscript. I wish to thank Mr. G. W. Scotter for the loan of collections in the Lichen Herbarium of the Canadian Wildlife Service. To Dr. C. D. Bird, thanks are extended for the use of the Lichen Herbarium at the University of Calgary. I should like to thank Miss Phoebe Hines for her good humor and speed in typing this thesis.

To my wife, Lynn M. Ostafichuk, I say; thank you.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION AND LITERATURE REVIEW	1
MATERIALS AND METHODS	19
Materials	19
Methods	19
Abbreviations used	22
Glossary	23
<u>PELTIGERA IN ALBERTA</u>	28
Key to the genera of Peltigeraceae	28
Key to the species of <u>Peltigera</u>	28
<u>Peltigera aphthosa</u>	30
<u>Peltigera canina</u>	37
<u>Peltigera evansiana</u>	49
<u>Peltigera horizontalis</u>	50
<u>Peltigera lepidophora</u>	52
<u>Peltigera malacea</u>	52
<u>Peltigera membranacea</u>	55
<u>Peltigera polydactyla</u>	56
<u>Peltigera pulverulenta</u>	59
<u>Peltigera scutata</u>	63
<u>Peltigera venosa</u>	63
Distribution of <u>Peltigera</u> in Alberta	65

A STUDY OF THE PELTIGERA CANINA COMPLEX

68

Preliminary discussion

69

The polygonal graph method

74

Analysis of selected collections

82

Summary

89

REFERENCES

92

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Photograph of cephalodia	25
2	Photograph of isidia	25
3	Photograph of pilose surface of a rhizine	25
4	Photograph of simple rhizines	25
5	Photograph of fibrillose rhizines	26
6	Photograph of fasciculate rhizines	26
7	Photograph of squamules at borders of cracks	26
8	Photograph of velutinate surface of rhizines	26
9	Photograph of under surface of <u>Peltigera polydactyla</u>	27
10	Photograph of under surface of <u>Peltigera pulverulenta</u>	27
11	Photograph of under surface of <u>Peltigera canina</u>	27
12	Photograph showing character of under surface of <u>Peltigera canina</u>	62
13	Photograph showing character of under surface of <u>Peltigera pulverulenta</u>	62
14	Map of study area	67
15-24	Maps showing distribution of the species and varieties most frequently collected	67

25	Map showing distribution of species with isidia and forms with squamules	67
26	Key for constructing polygonal graphs	80
27-38	Reference key and polygonal graphs of selected specimens	81
39-41	Superimposed polygonal graphs	86

INTRODUCTION AND LITERATURE REVIEW

The study of lichens has lagged behind that of other organisms because of the dual nature of the thallus. This duality, from the time it was noted in 1867, has been a source of controversy and to this day agreement has not been reached concerning the question - what is a lichen? This question does not arise in the study of single organisms. Species concepts in lichens are based on morphological characters, but because of the lichen's apparent simplicity distinctive morphological characters are few in number and, in contrast to characters in most plants and animals, those characters of the lichen which are available cannot be related to genetic or fossil evidence. Nor can the characters upon which lichen species are based be evaluated through growth and developmental studies in the laboratory since satisfactory methods for culturing them are not available. Furthermore, study of growth and development of the thallus in the field is severely hampered by the exceedingly slow growth of lichens as well as lack of standardized environmental conditions. Additionally, lichen taxonomy is still almost entirely in the pioneer stage where a collection must be named without knowledge of how other members of the same species react throughout the range of that species. An inherent problem of the pioneer or cataloguing phase of taxonomy of a large group is that it is unavoidable that species will be named as distinct when they are in fact variations of a single species. The confusion which is caused in the nomenclature by having several names for the same species is troublesome. The International Code for Botanical Nomenclature attempts to minimize nomenclature confusion and states explicitly that lichens are to be regarded as fungi for purposes of naming. However, regarding the lichens as fungi is

not proving to be an altogether satisfactory solution to classifying lichens in the over-all classification of living things. Examples of how lichens are treated in comprehensive classifications of organisms are to be had in biology texts such as Marsland (1957) or Weisz (1963): they are simply ignored. Each investigator must formulate his own philosophy concerning such problems as the nature of a lichen, species concept and application of names if he is to be consistent within his area of investigation.

The preceeding remarks indicate the current state of lichenological studies and it was felt that a discussion of some of these problems was a necessary prelude to an account of research reported in this thesis.

According to Fink (1910) Tournefort in 1694 was the first botanist to classify the lichens as a distinct group of plants. Previously they had at various times been regarded as algae, fungi, mosses, and liverworts. In 1864 de Bary observed that some lichens suggested a Nostoc being attacked by a fungus. Schwendener, in 1867, enlarged upon this and concluded that all lichens were fungi parasitic upon algae. Criticism of this concept on the grounds that the alga did not suffer and that the lichens were long-lived caused Schwendener to revise his opinion that the relationship was a parasitic one. In 1869 he proposed the term helotism to indicate a relationship in which the algae were "slaves" of the fungus. The theories of parasitism and later helotism were replaced by the mutualistic symbiosis or consortium theory which is credited to Reinke, 1872, 1894, and which was supported by van Tieghem, 1874, and de Bary, 1879. In this theory the lichen was supposed to be a perfectly balanced association in which the alga provided food for the fungus while the fungus provided the alga with salts from the substrate and

protection from drying. The result was a partnership in which both members benefited. The theory of mutualistic symbiosis was accepted by botanists and won many strong supporters, perhaps none more staunch than Famintzin who is reported to have indicated in 1907 that the plastids of green plants had to be regarded as symbionts.

As further observation on lichen structure were made it became evident that the mutualistic theory did not agree with the facts. It was noted, for example, that the fungus offered rather limited protection against drying to the alga and that the transport of salts from the substrate to the alga was not of any great benefit to the alga since free living algae could grow and multiply abundantly in the absence of any fungus and in the same environment as the lichen. Other theories arose. In 1902 and 1904 Elenkin observed dead algal cells in a lichen thallus and proposed a theory of endosaprotrophism in which the fungus killed the algal cells by chemical means and then lived saprotrophically on these dead cells. In 1923 observation of apparently the same thing led Bachmann to think that the dead algal cells were water reservoirs, and he looked upon the dying of these cells as a sacrifice for the benefit of other parts of the thallus. According to Quispel (1943) Moreau thought of the symbiosis as a chronic infection with the fungus as the host and the alga as the pathogen. This view is in contrast to Schwendener's who thought the viewpoints of these men differed concerning the details of the association, both saw the symbiosis as a case of parasitism rather than mutualism.

Quispel (1943) has reported on the lichen symbiosis from information obtained in a study of an association of Protococcus and an unidentified fungus growing on bark of oak trees. He says that this represents a

less complex symbiosis than that which exists in the lichens and that where possible his results were tested on true lichen fungi. Of the lichen fungi the only one obtained in pure culture was the fungal component of Xanthoria parietina. Quispel cultured and investigated the nutrient requirements and some of the metabolic products of each member of the Protococcus and fungus association. In addition, he investigated the water relations of the two growing together. From his investigations he concludes that the lichen symbiosis is a mutualistic symbiosis but that it may under certain conditions take other forms. In addition, he states emphatically that the symbiosis depends upon the exchange of 'nutriles' which he defines as "vitamines, hormones, growth factors, accessory substances etc." Quispel says more about lichens than his experiments justify since most of his conclusions are based upon an association which probably should not be considered a lichen.

Tobler in 1925, according to Quispel, distinguished lichen symbiosis from other cases of symbiosis on three features. Firstly, the lichen symbiosis has a metabolism characterized by the production of lichen acids, secondly it results in a morphological unity and finally the lichen symbiosis has its own type of reproduction in the soredia which transmit both parts together. On the other hand, Quispel does not consider the formation or accumulation of the lichen acids as a feature of a lichen metabolism distinct from a fungal or algal metabolism. The lichen as a morphological unity, he indicates, is no different from a gall as a morphological unity, and the simultaneous reproduction of both members in a symbiosis is not restricted to lichens. Quispel concludes that the lichen symbiosis does not differ from other symbioses and that the lichen is in reality a physiological state.

The points he raises are crucial to the taxonomy of lichens, but since Quispel worked mainly with a loose association of an alga which does not occur in lichens, as commonly recognized, and an unidentified fungus, some of his conclusions may not be valid. It seems to me that he is not justified in applying information obtained from a loose association of an alga and a fungus to the more elaborately organized lichen thallus.

Quispel's interpretation may be questioned but studying the symbiosis through cultural methods, as he and others have done is a sound approach to an understanding of the symbiosis. Prominent in this area of investigation are Hendricksson (1958, 1964), who has worked with the fungal and algal components of Collema, and Ahmadjian (1958, 1959, 1961), who has worked with the two components from a number of lichens and has come to be regarded as the leading investigator in this field. His investigations center on the behaviour in culture of the components and have shown that the alga and fungus behave in culture much as their free living counterparts do. He has also attempted to synthesize a lichen by putting together the two members after they had been isolated and grown in culture. His experiments have resulted in the formation of an association which resembled soredia; a few algal cells enmeshed in a network of hyphae. The formation of this association depended upon bringing the two components together in a medium deficient in nutrients. Ahmadjian's findings are essentially in agreement with those of Scott's (1960). Scott worked with discs of Peltigera grown in culture and found that the lichen retains its identity under conditions where nutrient levels, light intensity and moisture are in a delicate balance, and that if this balance is altered either the algal or the fungal component overruns the other.

The foregoing discussion indicates some of the points which must

be considered in drawing up a definition of a lichen and from what has been said one might suppose that the symbiosis must become the most important single point in a definition. However, a definition of a lichen based upon the symbiotic relationship has some serious flaws when applied to taxonomy.

In taxonomy the disadvantages of a definition based upon physiological relationship are both practical and theoretical. The practical implication is that one must establish the mechanism of the relationship before he can decide whether he is looking at a lichen or not. The objection upon theoretical grounds is that a definition which employs unknowns, in this case the factors governing the relationship between the alga and the fungus, is in reality not a definition. Factors governing the relationship have been studied and are not to be regarded as being totally unknown. However, it is clear that the relationship between the alga and the fungus is not a fixed one. Consequently, any definition dependent upon a variable relationship will in itself be variable and a source of confusion in classification.

I believe that in order to classify something one should establish clearly what is being classified. With single organisms the problem of what is being classified scarcely exists. Even in instances where there is a close association between two organisms, each member can be referred to its appropriate place in the classification of living things and considered separately as a taxonomic entity. The question of the interaction between the organisms has no bearing upon how they are classified. The same thing can be done with the lichens. The algal component can be classified in the system set up for the algae and the fungal component in its appropriate category. If one follows that

procedure he discovers that he has classified the lichen out of existence.

While the question of interaction is peripheral to the taxonomy of most organisms it becomes central to the taxonomy of lichens which exist as a product of interaction between an alga and a fungus. There are, of course, other products of interaction between organisms and a definition of a lichen based on interaction requires a great deal of qualification which, together with the varying interaction makes such a definition unsatisfactory for taxonomic purposes.

Of the definitions of a lichen which I have seen one has impressed me as being concise and to the point. That is the definition given by Lazo and Klein (1965) who say that a lichen is "a structurally organized entity consisting of the permanent association of a fungus and an alga."

The significance of Lazo and Klein's definition is that it emphasizes the lichen as a structural entity. There is no doubt in this definition that the lichen is a thing and not a concept, a point not altogether clear in definitions having the interaction between alga and fungus as the major consideration.

If one accepts lichens as structural entities he is able to consider them as morphologically and taxonomically equivalent to single organisms and the concept of species applies in the same way it does to single organisms. If he does not accept lichens as single organisms for purposes of classification then he is forced to apply the species concept to an equally indefinite "lichen concept", which to me seems a combination overwhelming in its formidability.

This study concerns itself with taxonomy and the effect of environment upon morphological characters and I believe that it is necessary to define the lichen as a single organism for such work. It must be pointed

out, however, that this view is not in agreement with Article 13, note 4 of the International Code of Botanical Nomenclature which states "for nomenclatural purposes names given to lichens shall be considered as applying to their fungal component". Culberson (1961) has examined this rule and has described it as un-realistic. He says, "A strict adherence to this rule means the acceptance of suppositions which are questionable or plainly wrong." The main assumption which must be accepted is that the algal component contributes nothing to the lichen and that, as a consequence, the same taxonomic category will be arrived at regardless of whether the lichen or only the lichen fungus is considered.

Examination of lichens reveals the algae contributing to the substance and the color in varying degrees. In addition, the occurrence of the lichen acids, substances unique to the lichen and apparently not produced by the alga or fungus by itself, is indication that ignoring the alga is not justified. Work reported by Hale (1957), suggests that if the alga is ignored quite different taxonomic conclusions can be drawn. In his work the fungal component of the lichen Buellia stillingiana was isolated and in culture produced conidia which led to its identification as the deuteromycete Sporidesmium folliculatum, a common wood inhabiting saprobe of eastern North America.

Further evidence that the rule is unrealistic can be found in any key to a large group of lichens. The key to genera of crustose lichens in Hale (1961) offers a number of examples. The lichen genera Cyphelium and Pyrgillus are separated on the basis of the genus of alga present: in Cyphelium it is Trebouxia while in Pyrgillus it is Trentepohlia. The same two algae serve as the basis for separating groups of genera elsewhere in the key. In Lichina the alga is Rivularia, in Heppia it is Nostoc,

and Gloeocapsa, Chroococcus and Xanthocapsa are likewise used in determining a lichen genus or group of genera. The most used feature of the alga is the Division to which it belongs, whether Cyanophyta or Chlorophyta, which serves in making broad distinctions in classification. At the species level algae have been little used because of the extreme difficulty in identifying them to species or even genera when they are in the lichen, as has been pointed out by Ahmadjian (1958).

A rule of nomenclature, whatever its shortcomings, cannot be blamed for the confusion in lichen taxonomy. Rather, its inadequacy should be interpreted as a symptom, and the cause for confusion looked for elsewhere.

Martin (1961) says in regard to the formulation of nomenclatural rules, "For such purposes we must accept organisms as we find them, not as we think they ought to be."

While rules can be drawn up to guide one in the use of names and the names fixed by type specimens, rules are of little help in deciding whether a particular specimen is sufficiently like the type to warrant its being called the same thing; that is, whether the two are the same species. In the flowering plants the genetics, development and flower structure provide what appear to be stable points of reference in deciding whether two specimens are of the same species. Similarly, in zoology, genetical, developmental and structural features provide points of reference in classification. In bacteriology where morphological features are few and reproduction is by fission, features of a chemical nature such as: reactions to stains, nutritional requirements and products synthesized, play the major role in providing information for classifying the organisms. Of course most of this information depends

upon obtaining pure cultures of the organism, and culturing is not yet practicable with the lichen.

In all groups where there is sexual reproduction the structures most closely related to reproduction are generally considered to have the greatest taxonomic significance. Whether or not interbreeding results in fertile offspring serves as the core for most elementary definitions of species and such definitions are applied easily to a large portion of the vertebrates and flowering plants. Definitions of species based upon interbreeding and fertility begin to weaken when hybrids are considered and lose all value when dealing with asexually reproducing organisms. Whether or not lichens are totally asexual in their reproduction is not known, but at present sexual reproduction and genetics provide no basis for a definition of a lichen species.

For lichens, the definition of a species given by Fulford (1963) in connection with liverworts is applicable. She says, "a species is a group of individuals, essentially similar in all important characteristics." The decision as to what constitutes essential similarity and what is important is left to the resources and judgement of the taxonomist.

Lichen species are erected on the basis of similarities and differences just as are species in other groups, but at present one cannot relate these differences or similarities to reproduction, behaviour in culture, or fossil evidence for evaluation. For example, much of lichen taxonomy rests upon features of the sporophore whose function and significance are assumed rather than demonstrated. The tacit assumption is that the function of the lichen sporophore is the same as that of free-living fungi.

There is, however, one feature of lichens which has been seized

upon as having great potential for defining species, and that is their production of lichen substances. These substances are frequently referred to as the lichen acids, but are in fact a group of organic compounds which include acids, neutral substances, polyalcohols, and other complex compounds.

This aspect of lichenology originated with Nylander's discovery in 1866 that, when treated with a potassium hydroxide solution, some lichens produced colored compounds while others did not. From this beginning the chemistry of the lichen substances has developed to the point where the specificity of the tests is no longer questioned. Outstanding investigators in the study of the lichen substances are Asahina and Shibata (1954) who have contributed much to characterising these substances and to the development of simple and reliable microtechniques for demonstrating them. Some of the tests rely on color reaction and are easily evaluated. Others, though simple to perform, rely upon the identification of compounds from features of crystal morphology which requires some experience.

Many workers have used these techniques and, in most instances, where lichens have appeared to be the same morphologically but differed in chemistry closer examination has revealed morphological differences as well as differences in distribution or in habitat. In those instances where the ranges of morphologically identical but chemically different forms overlap, the only way to distinguish between them is on the basis of chemistry. Usually this distinction requires one to determine the presence or absence of a specific compound.

While the techniques of lichen chemistry are not questioned their careless application has been pointed out by Hale (1965). Understandably,

there is no general agreement on the use of the results for classification purposes.

Lamb (1951), working with the genus Stereocaulon, classified the morphologically similar but chemically different forms as chemical strains of the species recognized on morphological grounds. He did not include the chemical strains in the formal nomenclature but simply designated them by a number. Hale (1965) considers that a numerical or other informal designation, while satisfactory as a temporary expedient, is undesirable since it is not governed by rules of nomenclature and, as a consequence, is not stable. Hale suggests that the different chemical forms be recorded as species so that they, as trivial forms, would not be lost from the literature. He also points out that the recognition of chemical strains as separate species would minimize morphological affinities, and forms identical except for the chemistry might be widely separated in the classification.

Although Hale does not say so categorically it seems that he is in favor of regarding chemical strains as species when this can be reasonably done.

However, regardless of how chemical strains are to be incorporated into the taxonomy, the chemical features of a lichen appear to be some of its more constant characters. These features do not change with the age of the lichen nor are they modified by factors of the environment, according to Culberson (1958). Features as constant in their expression are all too rare in lichens and should be exploited to their fullest extent.

While the study of lichen acids has demonstrated their usefulness in resolving some problems in lichen taxonomy, it is by no means the way to solve all taxonomic problems.

Another approach to a sound lichen taxonomy lies in analyzing the morphological features and determining the way in which these are affected by environmental factors, an approach which has been almost totally neglected. In reality, present lichen classification is a synthesis of morphological characters whose variability is unknown. So long as the variability of these characters is unknown one cannot justify regarding any one character as more important than any other in delimiting varieties, species or genera.

A somewhat arbitrary synthesis is unavoidable in the preliminary stages of classification of a group, but if the classification is to grow in significance beyond cataloguing, analysis of the morphological features to determine how they are expressed under different environmental conditions is essential.

Weber (1962) has recognized some of these problems and, working with the crustose lichens, has divided the difficulties of lichen taxonomy into three parts. The first is concerned with the lack of knowledge of the origins, evolution and genetics of the lichens; the second is concerned with the relative simplicity and lack of taxonomically useful characters in the lichens; the third deals with the deficiencies of herbaria in number and quality of lichen collections, and the small number of specialists working on lichens. He emphasizes that because of the rock or soil substrate, specimens are often poor and also that information about the habitat is usually lacking in herbarium specimens.

Weber's paper is long but the substance of much that he says is that many species have been described which are in reality modifications due to environment and that much of this variation can be interpreted correctly if collections and field observations are adequate. These

views, while not original with Weber, are documented with examples emphasizing the importance of considering environment in lichen taxonomy. To indicate some of the implications the example of Lecidea decipiens can be cited. This species usually develops a cluster of small coral colored to whitish lobes on soil and is common in the badlands and on alpine tundra in Alberta. This lichen can grow on a variety of soils ranging from loose sandy to heavy clay and Weber says that the form of the thallus varies so much with type of soil that Lecidea decipiens thalli may be classified as Lecidea crenata, Psora concava or Lecidea coroniformis.

The above discussion has been concerned with problems common to the study of any group of lichens including Peltigera, which is the subject of the study reported in this thesis. I wish now to deal with this particular genus, reviewing the literature and pointing out specific problems connected with its taxonomy.

Peltigera is a flat, leaf-like lichen which grows on mosses and soil. The lobes are usually about two inches long but this is quite variable and the only generalization which applies is that Peltigera is definitely not microscopic; specimens with lobes less than a half inch across are not common. The upper limit in size of lobes is about five inches long and three broad.

The internal structure of Peltigera is as follows: upper surface a pseudo-parenchyma two to four 'cells' deep, sometimes with hyphae on the outer side; immediately below is a layer of algal cells, variable in number but usually about five cells deep; below the algal zone is the medulla which is a network of thick-walled hyphae and arising from the medulla and external to it are the veins and rhizines of the undersurface.

Extending through the algal zone are thin-walled, moderately branched hyphae which terminate as cortical cells on the upper surface and extend deep into the medulla on the lower.

The apothecia which are brown or blackish are borne at the tips of the lobes. In cross section an apothecium would reveal, reading from the deep seated parts to the outside, medullary hyphae of the thallus, the hypothecium which is a thin web of hyphae from which the hymenium originates; the hymenium which appears as a palisade composed of asci and paraphyses. The asci contain the long slender spores and are at various stages of maturity throughout the hymenial layer. The paraphyses are hyphal filaments, somewhat longer than the asci, with their tips enlarged, dark colored and cemented together producing an epithecium which may function as a protective layer over the asci.

Although the apothecium appears to have evolved as a device for producing spores over a long period of time, in marked contrast with sporulation in most ascomycetes, the function of these spores is uncertain. It has been speculated that after dispersal the spore germinates and if a suitable alga is encountered by the germ tube the lichen is reconstituted. This has not been demonstrated and vegetative reproduction by fragmentation of the thallus or through soredia is the only means for reproduction which can be demonstrated.

Peltigera is one genus whose chemistry has received very little attention and this may be due to the fact that Peltigera canina and some of the other species are apparently without those distinctive materials. Any preliminary investigation of this genus which involved only the more common Peltigera canina and its varieties, might not encourage one to pursue the matter further. But whatever the explanation, it now appears

that the chemistry could be useful in the taxonomy of Peltigera, and some distinctions made in this study have included chemical features to supplement the strictly morphological features.

The structure and development of the thallus, rhizines, isidia and soredia of species of Peltigera has been studied by Darbishire (1926, 1927). More recently Thomson (1948) and Lindahl (1959, 1960) have investigated the occurrence and formation of isidia in certain species of Peltigera and their conclusions are commented on in connection with Peltigera canina var. rufescens f. innovans, Peltigera polydactyla and Peltigera horizontalis.

The physiology of the Peltigera symbiosis has been investigated by Smith (1960a, 1960b, 1960c). His studies dealt primarily with rates at which nitrogen compounds are absorbed and utilized. Scott (1960) has also done work relating to nitrogen metabolism and has shown that Peltigera praetextata is able to fix atmospheric nitrogen. He also reports that in culture the symbiosis is dependent upon a delicate balance between levels of nutrients, light and moisture. Both Smith's and Scott's findings show that while absorption of nutrients is rapid and can occur from very dilute solutions, the rates at which the absorbed nutrients are utilized are slow.

While Weber states that modification is not a serious taxonomic problem in the foliose and fruticose lichens the present state of taxonomy in Peltigera, at least, which is one of the most studied of the foliose lichens, does little to substantiate such a view.

In connection with Peltigera canina, Thomson (1950) says, "The var. rufescens plants grow under such diverse conditions that it is no wonder that they vary sufficiently to make one who is not well acquainted with them in the field think that he sees new forms or varieties."

In his classification of the North American Peltigera species Thomson has recognized the importance of environmental factors such as moisture and temperature as a cause for variation, although in most instances he does not specify the factor. In acknowledging the effect of environment he has brought together as one species those forms he felt were variations of that species but which had been regarded as distinct species previously. For example, Thomson regards Peltigera erumpens as a growth phase of Peltigera spuria. Peltigera spuria is considered to be an "ecological or growth phase" or Peltigera canina. Thomson reduces Peltigera spuria from species to variety rank and Peltigera erumpens from species rank to form. When this is re-assembled it becomes Peltigera canina var. spuria f. sorediata in Thomson's monograph.

This classification can be criticized on the grounds that distinguishing varieties and forms in lichens is worthless when it has been demonstrated that environment induced variation can result in specimens being placed in different genera as was indicated in the example of Lecidea decipiens described by Weber. Furthermore, trinomials and quadriminomials are cumbersome and, since their use is not clearly defined in the code for botanical nomenclature, they can be a source of confusion.

The positive aspect of Thomson's classification, and one which should be fully appreciated, is that it represents the beginning of a classification of Peltigera in which affinities are based upon observations of the plant in its environment and not upon assumed relationships.

At the beginning of this study the most comprehensive information on Peltigera in Alberta was contained in a monograph by Thomson (1950) where he reports forty three collections distributed through seventeen taxa. Of this total twenty three are from Banff itself and, if all

collections from points within that general area are taken together, the total then becomes thirty five for the general Banff area. Two collections are from Slave River, one from Lesser Slave District and five are not traced as to location.

Information compiled by Bird (1966) does not alter the fragmentary picture of Peltigera in Alberta, but serves to emphasize the need for surveys of this and other lichen groups in this region.

The present study had two objectives. The first was to survey the genus Peltigera in western and southern Alberta; the second to investigate the problem of variability in Peltigera canina, the most frequently occurring species.

MATERIALS AND METHODS

Materials

The materials used in this study were collections of Peltigera species from a number of sources. The largest part of these were collected during this study. However, valuable additions to the total studied were made through the collecting done by others with this investigation in mind.

In addition, Peltigera collections in the following herbaria were examined: Cryptogamic Herbarium, Department of Botany, University of Alberta, Edmonton; Lichen Herbarium, Department of Biology, University of Calgary, Calgary, Alberta; Lichen Herbarium, Canadian Wildlife Service, Edmonton.

Detailed listings of collections examined are presented under the species considered.

Methods

As noted in the Introduction this study can be divided into two parts; the first a survey of the Peltigera species found in Alberta; the second a detailed examination of P. canina.

The methods described here are those which apply to all species collected. Any methods which apply only to P. canina are dealt with in the section devoted to the detailed examination of that species.

There were two types of collection made. The first was the "small collection" where details of the habitat for an individual specimen were noted. For this type manila envelopes, $5\frac{1}{2} \times 7\frac{1}{2}$ ins. were used. The second type was the "bulk collection" which differed from the first in that no field notes relating to individual specimens were made. The procedure followed was to place all the specimens from a given site into one

bag; any notes relating to the collection would be concerned with the geographical location of the site, its major physical features and the type of vegetation prevailing.

To help clarify the term site the following situation will serve as an example: a rocky ridge with an east-west orientation on a gentle slope with some scattered spruce, lodgepole pine and under-story of Shepherdia canadensis and juniper, representing a fairly open and dry habitat. The sites in this example would be: the spruce-pine slope as one, the south-facing part of the ridge another and the north-facing side of the ridge the third. Where collecting was along a line which passed through a number of regions that differed in vegetation, altitude or physical features, each of the different regions would be considered a different site.

At the end of a day's collecting the envelopes or paper bags were stacked loosely, open ends upward, and allowed to dry. More elaborate procedures for drying were unnecessary.

As a final note with regards to collecting, I should like to emphasize that specimens were taken with substrate and any accumulated debris which acted as a support for the thalli. In addition, the substrate and debris lying on the thallus was not removed and this material provided useful information about the habitat of the lichen.

In the laboratory, rather than trying to remove the dry specimens of the bulk collections from a bag one by one, the bag was carefully torn away from the lichens. This left a loose bale of Peltigera and any associated lichens which could be taken apart easily with little damage to the specimen.

The filing system used employed two different sized containers for

the specimens and a larger tray to accommodate a number of the specimen boxes. The specimen boxes, of herbarium paper, were $4\frac{1}{2}$ x 6 x $1\frac{1}{2}$ ins. and $2\frac{3}{4}$ x $4\frac{1}{2}$ x $1\frac{1}{2}$ ins. in size; the trays, of cardboard, $18\frac{1}{2}$ x 12 x $1\frac{1}{2}$ ins. One such tray could accommodate eight of the large or sixteen of the small specimen boxes and the two sizes could be mixed in a tray. A number was assigned to the contents of each box; the first portion of the number was allocated to the collection in the field, the second part of the file number was applied to the contents of one specimen box. Where the collection placed in one specimen box was found to be a mixed one, two or more species growing together on the same portion of substrate, it was felt that useful ecological information would be retained by leaving it as a mixed collection and a third number would be added to the file number. Also, if what had been taken as a single species later proved to be a mixed collection it was filed in the same way. As an example, one portion of bulk collection 256 (Whitecourt, north-facing slope, about 20° , mature spruce, by creek, south end of town.) was a piece of rotted wood with Peltigera apthosa, P. polydactyla and P. canina growing more or less intermingled. The substrate with the three species was placed in one specimen box, no 2, and the association left intact. The resulting file numbers of the individual specimens then became:

256-2-1 P. apthosa
256-2-2 P. polydactyla
256-2-3 P. canina

This seemingly complex system for numbering specimens was developed out of the need for a system capable of growth from any point within itself. An unmodified serial system, with its growth from one end only, would have caused endless re-assignment of numbers. Both the bulk and the small collections were filed on a similar basis.

Another procedure which applied to all species collected is a test for the presence of crystalline materials in acetone extracts of the thallus. This was done by using glycerol-acetic acid (GE) and the technique described by Hale (1961). At the same time droplets of a lipid-like substance were looked for in the preparations.

These tests were done on a small group of collections for each species and not all specimens were examined.

Abbreviations used in connection with Reactions

K, Potassium hydroxide; C, calcium hypochlorite; KC, a mixture of potassium hydroxide and calcium hypochlorite; P, paraphenylenediamine. The preceding chemicals when applied to the medulla or cortex will give colors ranging from yellow to dark red when the reaction is positive and little or no change in color when the reaction is negative. I, is a solution of iodine in potassium iodide. GE is glycerol-acetic acid, 1:1. GE negative indicates that crystals were not observed; GE positive, that crystals were clearly demonstrated.

Abbreviations used in the lists of specimens examined

Herbaria:

(Alta), Cryptogamic Herbarium, Department of Botany, University of Alberta, Edmonton, Alberta.

(CWS), Lichen Herbarium, Canadian Wildlife Service, Edmonton, Alberta.

(U Calgary), Lichen Herbarium, Department of Biology, University of Calgary, Calgary, Alberta.

Collectors:

CDB, C.D. Bird; CDB&G, C.D. Bird and J.L. Glenn; CDB&L, C.D. Bird and E.J. Lakusta; CDB&S, C.D. Bird and J. Seaborn; GWS, G.W. Scotter; LLK, L.L. Kennedy; MO, M. Ostafichuk.

Glossary

AURICULATE. 'Ear shaped'. Like a cupped hand.

CEPHALODIUM. A small outgrowth on a lichen thallus which is like a miniature lichen in structure. Frequently contrasting in color with the part of the lichen upon which it rests (Figure 1, page 25).

CORTEX. Modified hyphae of the outer surface in lichens. Distinct from the central hyphae in that the cortex is cellular in microscopic cross section, whereas the central hyphae retain their fungal identity.

CRISPED. Finely curled or crinkled.

INVOLUTE. Curled inward or onto the upper surface.

ISIDIA. Cylindrical or coraloid outgrowth of hyphae and algal cells, located randomly on the upper surface of the thallus (Figure 2, page 25).

LOBE. The largest portion of Peltigera thallus to include a continuous area bounded on three sides by the lobe margin, the fourth grading into older, degenerating or erroded thallus.

MEDULLA. The central portion of a lichen, composed of interwoven hyphae. In Peltigera, that part of the undersurface lying below the algal zone but excluding the veins and rhizines.

PILOSE. Covered with long, soft, hairy compactly arranged filaments. A somewhat shaggy pile, like plush (Figure 3, page 25).

REVOLUTE. Curled outward or onto the lower surface.

RHIZINE. A root-like extension of fungal tissue from the under side of a thallus, made up of strongly coalescent, longitudinally oriented hyphae.

Simple rhizine. Rhizine composed of a single bundle of hyphae (Figure 4, page 25).

Fibrillose rhizine. Rhizine composed of a number of discrete, slender bundles of hyphae growing close together to produce somewhat tangled tufts or fringes on veins (Figure 5, page 26).

Fasciculate rhizine. Rhizine composed of a group of slender simple rhizines anastomosed to form a single larger rhizine (Figure 6, page 26).

SOREDIA. Granular mass, each granule (soredium) consisting of one to several algal cells held in a mesh of hyphae. Function as vegetative propagules.

SQUAMULE. Flattened outgrowth of hyphae and algal cells, located at cracks, wounds or margins of thallus (Figure 7, page 26).

THALLUS. The vegetative portion of a lichen. In Peltigera this may be a group of lobes in close association resulting in a definite plant-body, often rosette-like or clearly derived from this habit; it may be a somewhat loose association of lobes indefinite in their arrangement; or it may be scattered lobes having only little contact with each other.

VEINS. Interwoven and longitudinally oriented hyphae raised from, but merging with the medulla resulting in a macroscopic network on the under surface of some lichens (Figures 9 - 11, page 27).

VELUTINATE. Coated with short, fine, soft, hairy filaments vertically and compactly, like velvet (Figure 8, page 26).

Figure 1. Cephalodia on upper surface of Peltigera aphthosa (x 2).

Figure 2. Isidia on upper surface of Peltigera evansiana (x 10).

Figure 3. Pilose surface of a mature rhizine of Peltigera pulverulenta (x 25).

Figure 4. Simple rhizines. Some tendency to the fasciculate condition, but compare with Figure 6, page 26 (x 10).

1



2



3



4



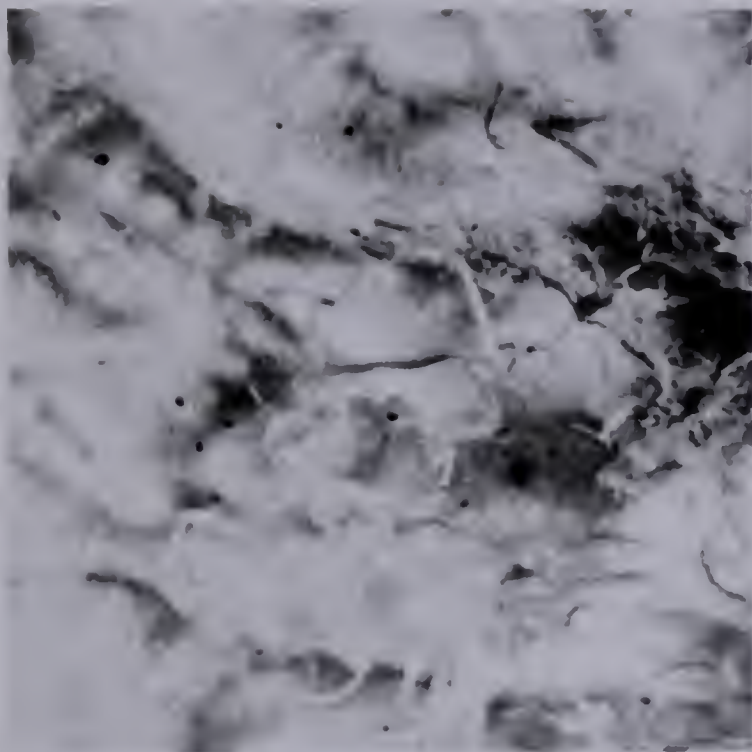
Figure 5. Fibrillose rhizines of Peltigera canina var. canina f. sorediata (x 10).

Figure 6. Fasciculate rhizines of Peltigera canina var. rufescens (x 10).

Figure 7. Squamules at borders of cracks in Peltigera polydactyla (x 10).

Figure 8. Velutinate surface on rhizines of Peltigera membranacea (x 25).

5



6



7



8

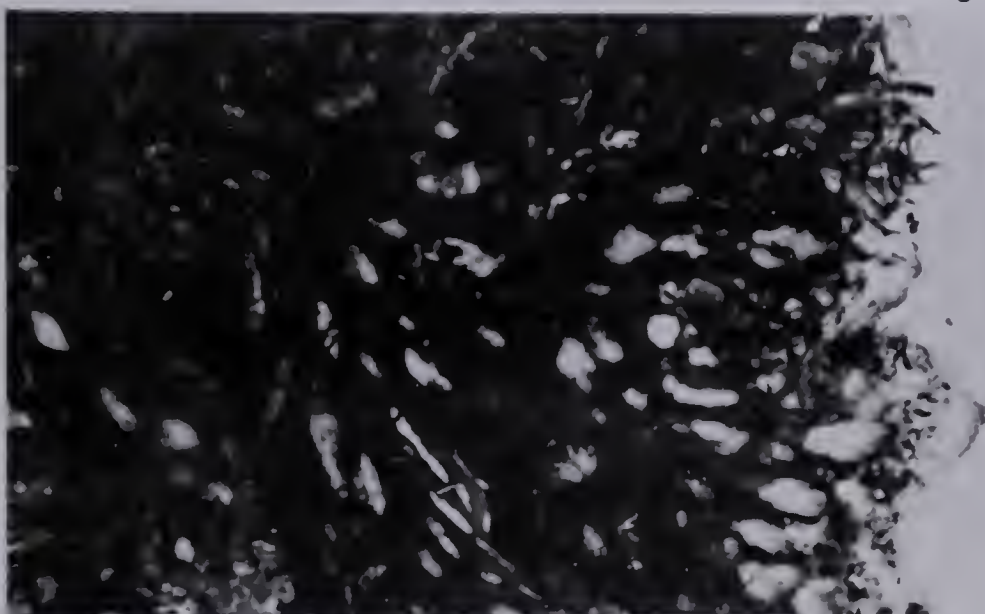


Figure 9. Under surface of Peltigera polydactyla showing broad, dark veins and small light colored interspaces (x 5).

Figure 10. Under surface of Peltigera pulverulenta with both broad veins and finer ones. This type of venation is intermediate between that of Peltigera polydactyla and Peltigera canina (x 5)."

Figure 11. Under surface of Peltigera canina showing the narrow, raised veins typical of that species (x 5).

9



10



11



PELTIGERA IN ALBERTA

Members of this group are thin or parchment-like foliose lichens with lobes ranging from about 1 - 15 cm in length and 0.4 - 10 cm in width. They grow mainly on mosses and soil. Some species of Nephroma may be firmly attached to rocks or wood, but usually the members of this group are loosely attached to the substrate by the rhizines of the undersurface.

Although there is a superficial resemblance between the genera, notably Peltigera and Nephroma, the distinctions are quite clear.

Key to the Genera of Peltigeraceae.

1. Apothecia on upper surface; lower cortex lacking or rudimentary --- 2.
1. Apothecia on lower surface; lower cortex well developed --- Nephroma.
2. Apothecia at tips of lobes; lower cortex lacking --- Peltigera.
2. Apothecia central; lower cortex rudimentary --- Solorina.

Peltigera Willd. emend L. Rabenh.

The following key to the species is designed to serve as a guide to the more commonly collected or 'typical' representatives of each species found in this region. Atypical forms can often be associated with the typical through intermediates if a collection is large enough. Small, isolated, atypical collections are difficult to classify.

Key to the Species of Peltigera.

1. Thallus with warty cephalodia on upper surface --- P. aphthosa.
1. Thallus without warty cephalodia on upper surface --- 2.
2. Apothecia horizontal at margin of lobe --- 3.
2. Apothecia ascending at margin of lobe --- 4.

3. Lobes 2 cm or less across, only slightly curled, veins separate and distinct --- P. venosa.
3. Lobes usually 3 - 4 cm across, much curled, veins anastomosing and indistinct --- P. horizontalis.
4. Upper surface with tomentum at tips of lobes --- 9.
4. Upper surface smooth or scabrid --- 5.
5. Lobes with or without squamules on upper surface or margin --- 8.
5. Lobes with soredia or isidia on upper surface or margin --- 6.
6. Lobes with isidia on upper surface --- P. evansiana.
6. Lobes with soredia on upper surface or margin --- 7.
7. Lobes with soredia at margin --- P. scutata.
7. Lobes with central patches of soredia --- P. canina var. canina f. sorediata.
8. Veins mixed, broad and narrow, interspaces large, hyphae of under surface loosely arranged --- P. pulverulenta.
8. Veins broad, interspaces small, hyphae of under surface compactly arranged --- P. polydactyla.
9. Under side uniform or with very small interspaces, tomentum at tips of lobes erect --- P. malacea.
9. Veins on underside prominent, tomentum at tips of lobes appressed --- 10.
10. Veins mixed, broad and narrow, hyphae of under surface loosely arranged GE crystal positive --- P. pulverulenta.
10. Veins narrow, hyphae of under surface compactly arranged, GE crystal negative --- 11.
11. Rhizines fasciculate, fibrillose or simple, surface of rhizines smooth to pilose --- P. canina.
11. Rhizines simple, velutinate --- P. membranacea.

Peltigera aphthosa (L.) Willd.

Thallus usually 15 - 30 cm, but ranges from 3 cm to over a meter across; lobes about 7 cm long and 4 cm broad, but may be 1 - 10 cm long and 0.8 - 6 cm broad; edges ascending, smooth to crisped. Shape indefinite or sometimes rosette-like. Upper surface smooth in the center with an erect tomentum at the margin, bright green when moist, leaden green when dry, sometimes brownish to dull black when moist or dry. Warty cephalodia scattered over the surface. Under surface pale at the margins, blackening toward the center of the thallus; without veins and covered with an even nap to distinctly veined; rhizines scattered, fasciculate, becoming dark nearer the margin of the thallus than does the medulla.

Cortex pseudo-parenchymatous, hyaline to brown, 22 - 55 μ thick. Algal zone continuous, 25 - 35 μ thick; algal cells of the thallus Chlorophyta (Palmellaceae), 2.5 - 6 μ in diameter; algal cells of the cephalodia Cyanophyta (Nostocaceae), 6 - 9 μ in diameter. Medulla 460 - 1350 μ thick, of very loosely interwoven hyphae 10 μ in diameter with a lumen of 6 μ , color of medullary hyphae hyaline at the margins becoming brown toward center of the lobes.

If veins are present, vein hyphae oriented in the direction of the vein; 12 μ in diameter with a lumen of 4 - 5 μ , darker than the adjacent medullary hyphae.

Apothecia usually 8 - 12 mm up to 16 mm across, on extended lobules, the sides reflexed, the margins becoming crenate, the reverse with a cortex at first, leaving scaly patches of cortex on the back of the larger apothecia; disc reddish brown to blackish brown, hypothecium brown, hymenium hyaline to pale brown; paraphyses simple, thickened and darkened at the tips to a red-brown; asci cylindrico-clavate, 80 x 12 μ ,

8-spored; spores acicular, 3 - 9-septate, 45 - 75 x 4 - 7 μ .

Reactions: K negative, C negative, KC negative, I stains the young asci blue, GE lipid positive, crystal positive.

Habitat: On decaying litter, rotting logs and stumps, mosses, including feather moss (Hylocomium, Aulacomnium, Hypnum.) and on soil. Usually in moist locations, but sometimes on sunny slopes in open woods and similar exposed dry places.

Comments: The outstanding features of this species are: bright green color and scattered dark cephalodia when moist; conspicuous white margins of the undersurface, and the generally large size which makes this one of the more easily recognized species if one is dealing with material from moist, moderately shaded habitats. Specimens from dry habitats are frequently some shade of brown with little or none of the characteristic apple-green color in evidence and a specimen collected in alpine tundra was quite black except where the lobes had curled under a small ledge of earth and apparently received some protection from the elements. In all non-green specimens the presence of cephalodia, which can be detected without magnification, serves to settle any question as to identity.

Key to the Varieties and Forms of Peltigera aphthosa.

1. Underside uniform --- P. aphthosa var. aphthosa.
1. Underside with dark veins --- 2.
2. Lobes auriculate or crisped --- 3.
2. Lobes neither auriculate nor crisped --- P. aphthosa var. variolosa.
3. Lobes auriculate --- P. aphthosa var. variolosa f. complicata.
3. Lobes crisped --- P. aphthosa var. variolosa f. crispa.

It must be noted that the one variety grades completely into the other and intermediates cannot be placed with certainty using the presently accepted criteria.

Peltigera aphthosa (L.) Willd. var. aphthosa.

Thomson reports that this variety is the prevalent one in northern areas and in the mountains. However, present work suggests that any generalization in terms of major climatic or geographic regions is of rather limited use in recognition of varieties. Conditions of the micro-habitat are undoubtedly of considerable importance and there is a tendency for variety aphthosa to be the one prevalent under cool, moist conditions such as exist where there is a good growth of feather mosses in moderately dense woods.

Specimens Examined:

ALBERTA: Crimson Lake, MO 141, 155, 156, 164, (Alta); Nordeg, J. Wheelock w5, (Alta); Whitecourt, MO 254-7, 255-3, 255-13, 256-5, (Alta); Peace River, Moss 8885, 9937, (Alta); Elk Island N.P., GWS 628, (CWS); Edmonton, GWS 695, (CWS); Devon, MO 114, (Alta); Nojack, A.W.L. Stewart June 17, 1965, (Alta); Entrance Prov. Park, LLK 734a-3, (Alta); Jasper N.P., Old Fort Point, GWS 856, (CWS); Jasper N.P., Athabasca Falls, GWS 805 (CWS); Jasper N.P., Jasper, P. Stringer July 27, 1965, (U Calgary); Jasper N.P. Pyramid Lake, P. Stringer Aug. 6, 1965, (U Calgary); Jasper N.P., Mount Edith Cavell, P. Seymour July 17, 1965, (Alta); Jasper N.P., Whistler's Mt. MO 175-3, (Alta); Jasper N.P., Mount Edith Cavell, MO 226-9, 226-10, (Alta); Jasper N.P., Athabasca Falls, MO 274-1, 274-2, 274-3, 274-4, (Alta); Jasper N.P., Maligne Lake, MO 227-2, 227-9-1, 227-14, (Alta); Jasper N.P., Jonas Creek, MO 233-8, (Alta); Jasper N.P., Parker Ridge, MO 236-2, (Alta);

Banff N.P., Waterfowl Lakes, MO 239-5-1, (Alta); Banff N.P., Sundance Canyon, MO 241-9, (Alta); Banff N.P., Lake Louise, MO 246-3-1, (Alta); Banff N.P., Moraine Lake, MO 252-12, 271-11, 271-12, (Alta); Spring Lake, CDB&S 9337, (U Calgary); Turner Valley, CDB 8653, (U Calgary); Pincher Creek, CDB&L 14770, 15024, (U Calgary); Gap Ranger Station, CDB&L 15937, (U Calgary); Waterton Lakes N.P., Cameron Lake, MO 260-6, (Alta); Waterton Lakes N.P., Crandell Mt. MO 262-31, 262-32, 262-33, 262-34, 262-35, 262-36, 262-37, 262-38, (Alta); Waterton Lakes N.P., Red Rock Canyon, MO 264-1, 264-2, 264-3, 264-4, 264-5, (Alta); Waterton Lakes N.P., Red Rock Canyon GWS 714, (CWS); Waterton Lakes N.P., Blakiston Falls, MO 265-17, 265-18, 265-19, (Alta).

BRITISH COLUMBIA: Mount Robson, MO 230-6, (Alta); Yoho N.P., Takakkaw Falls, MO 249-6, (Alta); Kootenay N.P., McLeod Meadows, MO 268-9, 268-10, 268-11, 268-12, 268-15, (Alta); Dawson Creek, H.J. Brodie June 4, 1966, (Alta).

NORTHWEST TERRITORIES: GWS 1613, 1664, 1886, 1940, 2158, 2193, 2822, 2872, 3064, 3764, 3810, 3850, 4094, (CWS); L. Hills 1964, (Alta).

MANITOBA: J. Looman 643001, (U Calgary).

ONTARIO: J.A. Bailey 1344, (U Calgary).

COLORADO: S. Shushan s1-214, 21-1414, s1-4718, (U Calgary); S. Shushan and R. Anderson s17,966, (U Calgary); H.A. Sierk 2481, (U Calgary); CDB 10706, (U Calgary).

Peltigera aphthosa var. variolosa (Mass.) Thoms.

Within the area studied there was some indication of the variety variolosa being the more frequently occurring variety southward and away from the mountains. However, as pointed out in connection with the variety aphthosa, distribution provides little help in recognition of varieties.

Of the Alberta collections of Peltigera aphthosa two-thirds were the variety variolosa.

Specimens Examined:

ALBERTA: Crimson Lake, MO 122, 130, 169, (Alta); Crimson Lake, LLK 695, (Alta); Whitecourt, LLK Sept. 6, 1961, (Alta); Whitecourt, J. Dugle June 24, 1961, (Alta); Whitecourt, MO 254-6, 256-2, (Alta); Harmon Valley, J. Looman 641305, (U Calgary); Valleyview, J. Looman 641501, (U Calgary); High Prairie, Moss Aug. 5, 1947, (Alta); Battle River Valley, Moss July 15, 1931, (Alta); Muir Lake, E. Bozniak Sept. 14, 1965, (Alta); Devon, MO 113, (Alta); Wabamum, MO 259-8, 259-9, 259-11, (Alta); Hinton, LLK 734a-1, 734a-2, (Alta); Hinton, MO 173g, (Alta); Jasper N.P., Celestine Lake, P. Stringer July 19, 1965, (U Calgary); Jasper N.P., Maligne Lake, MO 227-3-1, 227-10, (Alta); Jasper N.P., Jonas Creek, MO 233-4, 233-11, 233-12, (Alta); Jasper N.P., Parker Ridge, MO 236-5, (Alta); Jasper N.P., Wilcox Peak, MO 238-1, (Alta); Banff N.P., Waterfowl Lakes, MO 239-3, (Alta); Banff N.P., Lake Louise, MO 243-2, 244-1, 244-5, 245-9, 246-3-2, (Alta); Banff N.P., Moraine Lake, MO 252-2, 271-10, (Alta); Banff N.P., Moraine Lake, CDB 7619, 7625, (U Calgary); Banff N.P., Larch Valley, MO 269-12, 269-13, (Alta); Banff N.P., Johnson Canyon, T. Lawson 37, (U Calgary); Banff N.P., Sunshine Creek, C.E. Beil 308, (U Calgary); Banff N.P., Goat Creek, C.E. Beil 1965, (U Calgary); Waiparous Creek, CDB&G 13250, 13295, 13327, 13360, 13402, (U Calgary); Ghost Ranger Station, CDB&G 11256a, 11284, 11318, (U Calgary); Devil's Head Mt., CDB&G 12816, (U Calgary); Canmore, CDB&G 12930, (U Calgary); Morley, CDB&G 14039, (U Calgary); Kananaskis Lakes, CDB&G 13451, 13901, 13920, 12956, 12975, 13043, 13054, 13070, 13114, 13152, (U Calgary); Spray Lake, CDB&G 13185 (U Calgary); Elbow Lake, CDB&G 13551, 13560, (U Calgary); Seebe, CDB&G

13674, (U Calgary); Barrier Reservoir, CDB&G 13813, (U Calgary); Turner Valley, CDB&G 11545, 11743, 11827, (U Calgary); George Creek, CDB&G 11951, (U Calgary); Little Elbow River, CDB&G 12319, (U Calgary); Highwood River Ranger Station, CDB&G 12558, 12591, 12617, 12663, 14051, 14090, 14147, 14197, (U Calgary); Millarville, CDB&G 14232, (U Calgary); Bragg Creek, CDB 14341, (U Calgary); Livingstone Falls, CDB&L 15691, (U Calgary); Mount Erris, CDB&L 15726, 15746, 15754, (U Calgary); Gould Dome, CDB&L 15769, (U Calgary); Trap Creek, CDB&S 9421, (U Calgary); Highwood Pass, R.W. Kobylnyk 56, (U Calgary); Wilemen Creek, CDB&S 9498, (U Calgary); Bragg Creek, CDB 8878, (U Calgary); Maycroft, W.W. Jeffrey Aug 25, 1962, (U Calgary); Oyster Creek, W.W. Jeffry Aug. 4, 1962, (U Calgary); Straight Creek, W.W. Jeffrey Aug. 7, 1962, (U Calgary); Pasque Creek, W.W. Jeffrey Aug. 1, 1962, Aug. 3, 1962, (U Calgary); Waterton Lakes N.P., Crandell Lake, CDB&L 15044b, 15047, 15056, (U Calgary); Waterton Lakes N.P., Crandell Mt. MO 262-1, 262-2, 262-25, 262-44, (Alta); Waterton Lakes N.P., Red Rock Canyon, MO 264-30, (Alta); Waterton Lakes N.P., Red Rock Canyon, GWS 713, (CWS).

BRITISH COLUMBIA: Yellowhead, MO 228-1, 228-4, (Alta); Mount Robson, MO 229-7, 229-8, 230-2, (Alta); Yoho N.P., Emerald Lake, MO 247-3, 247-4, (Alta); Yoho N.P., Takakkaw Falls, MO 248-4-1, (Alta); Kootenay N.P., McLeod Meadow, MO 268-13, (Alta); Vancouver Island, R.D. & L. Bird 38, (U Calgary); Vancouver Island, LLK 742, 744-1, (Alta).

NORTHWEST TERRITORIES: GWS 1508, 1740, 1958, 2560, 3977, 4052, 1771, (CWS); R. Freiling 15, (U Calgary).

SASKATCHEWAN: J. Looman 634302, 634901, 643903, (U Calgary).

MANITOBA: J. Looman 621902, 636106, (U Calgary).

NOVA SCOTIA: GWS 1:6193, (U Calgary).

COLORADO: CDB 10735, (U Calgary).

Peltigera apthosa var. variolosa f. complicata (T.Fr.) Zahlbr.

The few collections placed as this form could have been interpreted as juvenile thalli of the variety. However, to avoid obscuring what could possibly prove to be a distinct taxonomic group I have used this designation where it seemed applicable.

Specimens Examined:

ALBERTA: Crimson Lake, MO 168, (Alta); Jasper N.P., Mount Edith Cavell, MO 226-14, (Alta); Banff N.P., Cirrus Mt., MO 238a-3, (Alta); Wilemen Creek, CDB&S 9495, (U Calgary).

NORTHWEST TERRITORIES: GWS 4431, (CWS).

Peltigera apthosa var. variolosa f. crispa (Vain.) Zahlbr.

This form presents some difficulty in that the degree of crisping appears to be continuous, ranging from no crisping to extreme crisping. The specimens which have been placed as this form have shown marked crisping and have had smaller lobes than the variety.

I have noted the variety and the crisped form growing within a few feet of each other and Dr. C.D. Bird (Personal communication) had made similar observations. Whether the observed differences are inherent or reflect the influence of the micro-habitat is not known and further study in the field is needed. From present knowledge I would suggest that it is worth while to recognize this form and to make close comparisons between it and the variety whenever the opportunity presents itself in the field.

Specimens Examined:

ALBERTA: Crimson Lake, MO 138, 144, 148, 166, (Alta); Whitecourt, MO 254-11, 257-6, (Alta); Devon, MO 115, (Alta); Wabamum, MO 259-7, (Alta);

Ghost Ranger Station, CDB&G 11319, (U Calgary); Gorge Creek, CDB&G 12018, (U Calgary); Ford Creek, CDB&G 12248, (U Calgary).

COLORADO; H.A. Seirk 2384, (U Calgary).

Peltigera canina (L.) Willd.

Thallus usually 5 - 15 cm, but ranges from 1 to over 30 cm across, lobes usually 1.5 - 4 cm broad and 3 - 5 cm long but may range from 0.2 - 8 cm broad and 1 - 15 cm long; marginal region involute to flat, frequently becoming revolute at the edges; margins smooth to crisped. Thallus shape rosette-like to indefinite. Upper surface smooth, scabrid, sorediate or tomentose in the center, tomentose at the margin, tomentum dense to webby, sometimes absent, or present as a trace on only a few lobes of the thallus. Sometimes with squamules bordering cracks, wounds or at the margins of the lobes. Color usually a light brownish-gray, rusty or light slate-gray when dry, becoming much darker and frequently a dull dark green when moist. Under surface with a prominent network of raised white to brown veins. Rhizines dense to scattered; fasciculate, fibrillose or simple, sometimes forming a confluent spongy mat below.

Cortex pseudo-parenchymatous, hyaline to dark brown, 30 - 70 μ thick. Algal zone continuous, 40 - 100 μ thick, algal cells of the thallus Cyanophyta (Nostocaceae) 4 - 8 μ in diameter. Medulla 125 - 500 μ thick, of compactly interwoven hyphae, 5 - 8 μ in diameter with a lumen of 3 - 5 μ , hyaline to dark brown. Central hyphae in veins oriented in the direction of the veins.

Apothecia 6 - 10 mm across, on extended lobules, the sides usually reflexed, the margin crenate; disc light brown, reddish-brown to black, hypothecium brown, hymenium hyaline to brown, paraphyses thickened and reddish-brown at the tips, asci cylindrico-clavate, 90 x 10 μ , 8 spored, spores

acicular, 3 - 7-septate, hyaline to yellowish, 23 - 72 x 3 - 6.5 μ .

Reactions: K Negative, C negative, KC negative, P negative, I stains the asci blue, GE lipid positive, crystal negative.

Habitat: On litter, rotting stumps and logs, on mosses, including the feather mosses as well as the less luxuriant ones, on soils ranging from heavy to porous sandy types, when on rocks the thallus is usually on a cushion of moss. Found in situations ranging from densely shaded and moist to fully exposed and very dry.

Comments: As presently defined this species is identified chiefly by the presence of narrow, raised veins on the under surface and the presence of some tomentum on the upper surface. In most collections these two features are sufficiently distinct that the specimens can be placed as Peltigera canina without hesitation. In some collections, though, the tomentum can be almost completely obscured by a pruina-like encrustation. However, close examination of the margins at the tips of the lobes will usually reveal some trace of tomentum. In other collections the tomentum appears to be loosely attached and as a consequence of weathering, presumably, the upper surface may be quite smooth. When this is the case a small collection of just a few lobes may be difficult to place whereas a larger one might include some lobes showing a trace to moderately abundant tomentum.

Key to the Varieties and Forms of Peltigera canina

1. Upper surface with soredia in patches --- P. canina var. canina f. sorediata.
1. Upper surface smooth or with squamules --- 2.
2. Upper surface with squamules --- P. canina var. rufescens f. innovans.
2. Upper surface smooth --- 3.

3. Rhizines forming a spongy mat toward center --- P. canina var. spongiosa.
3. Rhizines discrete toward center --- 4.
4. Veins light colored throughout --- P. canina var. canina.
4. Veins partially or entirely dark --- 5.
5. Veins dark at center, light at margin --- P. canina var. rufescens.
5. Veins dark at center and at margin --- P. canina var. ulorrhiza.

Specimens having features of two or more of the varieties or forms are not at all uncommon and placement of such specimens has been according to the predominant key feature. A further point worth noting is that sometimes different parts of the same thallus can be placed as different varieties. These facts serve to emphasize that the sub-specific categories do not rest on a very firm foundation and, in practice, one should not be too disturbed if a particular specimen will not be fully accommodated by any one of the categories.

Peltigera canina (L.) Willd. var. canina.

Included in this variety are specimens classified as Peltigera canina and Peltigera canina var. albescens. This variety is somewhat more likely to occur in the more moist or shaded habitats than the variety rufescens, but this tendency is too uncertain to aid in identification.

Specimens Examined:

ALBERTA: Crimson Lake, MO 123, 131, 134, 163, (Alta); Harmon Valley, J. Looman 641306, (U Calgary); Hay Lakes, LLK Aug. 17, 1961, (Alta); Edmonton, MO 2, 5, (Alta); Edmonton, GWS 683, (CWS); Muir Lake, E. Bozniak Sept. 14, 1965, (Alta); Spruce Grove, A.W.L. Stewart Sept. 28,

1960, (Alta); Carrot Creek, MO 275-6, (Alta); Jasper N.P., Mount Tekarra, H.J. Brodie June 18, 1966, (Alta); Jasper N.P., Whistler's Mt., MO 175-1, (Alta); Jasper N.P., The Palisade, CDB 8703, (U Calgary); Banff N.P., Cirrus Mt., MO 238a-2, (Alta); Banff N.P., Lake Louise, MO 243-8, 243-9, 245-1, 245-7, 246-6-2, (Alta); Banff N.P., Larch Valley, MO 269-1, 269-2, (Alta); Banff N.P., Moraine Lake, MO 271-2, 271-3, 271-7, 271-8, 271-9, (Alta); Banff N.P., Banff, P. Stringer July 8, 1965, (U Calgary); Bragg Creek, CDB 8847, (U Calgary); Barrier Reservoir, CDB&G 13811, (U Calgary); Elbow Lake, CDB&G 13550, (U Calgary); Kananaskis Lakes, CDB&G 13453, (U Calgary); Waiparous Creek, CDB&G 13362, (U Calgary); Waterton Lakes N.P., Cameron Lake, LLK Aug. 10, 1961, (Alta); Waterton Lakes N.P., Cameron Lake, MO 260-5, 260-7, 260-8, (Alta); Waterton Lakes N.P., Mount Lineham, MO 261-8, (Alta); Waterton Lakes N.P., Cameron Falls, GWS 51, (CWS); Waterton Lakes N.P., Chief Mt., MO 266-1, 266-2, (Alta); Waterton Lakes N.P., Waterton, MO 263-6, 263-7, 263-8, (Alta); Waterton Lakes N.P., Crandell Mt., MO 262-13, 262-14, 262-15, 262-16, 262-17, 262-18, 262-19, 262-20, 262-21, 262-28, 262-29, (Alta); Waterton Lakes N.P., Red Rock Canyon, MO 264-11, 264-12, 264-13, 264-14, 264-15, 264-16, 264-17, (Alta); Waterton Lakes N.P., Blakiston Falls, MO 265-1, 265-2, 265-3, 265-4, 265-5, (Alta); Cypress Hills, LLK 730, (Alta).

BRITISH COLUMBIA: Mount Robson, MO 230-3, 230-4, (Alta); Fernie, MO 267-5, 267-6 (Alta); Manning Prov. Park, R.D. & L. Bird 86, (U Calgary); Vancouver Island, LLK 737, 743, (Alta).

NORTHWEST TERRITORIES: GWS 1502, 1961, 2148, 2199, 2559, 3806, 4136, (CWS); R. Paulson July, 1924, (Alta).

SASKATCHEWAN: J. Looman 620109, (U Calgary).

MANITOBA: J. Looman 621201, 621902, 636105, (U Calgary).

ONTARIO: C. E. Garton 7169, (U Calgary); J.A. Bailey 2538, 2540, (U Calgary).

ARIZONA: H.A. Sierk 2352, (U Calgary).

COLORADO: S. Shushan sl-1405, (U Calgary); H.A. Sierk 2440, 2472, (U Calgary).

UTAH: GWS 20, (CWS).

WYOMING: L. Wirth July 10, 1963, (U. Calgary).

Peltigera canina var. rufescens (Weis.) Mudd.

This is the most common variety and also the most variable. When it occurs in woods and moist habitats the shape of the thallus is likely to be indefinite and the lobes large in size. When on sandy, exposed or grassy sites the rosette-like shape is predominant and the lobes are small. Under alpine conditions a depauperate, rosette-like or indefinite shape in which the lobes are small and cracked is common.

Thomson uses size as one of the features for separating the variety rufescens from the varieties albescens (canina as defined here), and ulorrhiza. However, because any given size can occur with any type of undersurface I have not considered size in making varietal designations. In general, collections placed as the variety rufescens will include smaller specimens than the variety canina.

I have classified as variety rufescens specimens designated as Peltigera canina var. spuria and Peltigera spuria in collections examined. These have been specimens with small lobes from exposed or very dry locations. I felt that such specimens were better regarded as depauperate members of one of the varieties recognized here rather than as a distinct variety.

Specimens Examined:

ALBERTA: Crimson Lake, MO 120, 121, 125, 126, 127, 129, 133, 139-1, 142-1, 143, 145, 146, 147, 150, 151, 153, 154, 157, 158, 159, 165, 170, (Alta); Nordeg, J. Wheelock w1, w2, (Alta); Whitecourt, MO 254-1, 254-2, 254-3, 254-4, 255-4, 255-6, 255-8, 255-11, 255-12, 256-2-3, 256-8, 256-9, 256-11, 256-14, 257-4, 257-8, 257-10, 257-11, 254-8, (Alta); Elk Island N.P., GWS 625, (CWS); Elk Island N.P., MO 80, 81, 85, 87, (Alta); Miquelon Lakes, MO 200, 206, 208-1, 258-1, 258-2, (Alta); Hay Lakes, LLK Aug. 17, 1961, (Alta); Leduc, CDB 5407, (U Calgary); Edmonton, MO 1, (Alta); Edmonton, GWS 686, (CWS); Devon, MO 103, 104, 105, 107, 108, 109, 110, 111, 112, 116, 117, 118, 119, (Alta); Spruce Grove, A.W.L. Stewart Aug. 8, 1961, (Alta); Carrot Creek, MO 275-1, 275-2, (Alta); Hinton, MO 173d, 175i, 175k, (Alta); Jasper N.P., Athabasca Falls, GWS 806, (CWS); Jasper N.P., Old Fort Point, GWS 843, (CWS); Jasper N.P., Pyramid Mt., P. Stringer Aug. 6, 1965, (U Calgary); Jasper N.P., Jasper, C.E. Beil summer 1965, (U Calgary); Jasper N.P., Miette Hot Springs, C.E. Beil summer 1965, (U Calgary); Jasper N.P., Tangle Ridge, C.E. Beil 210, 214, (U Calgary); Jasper N.P., Punch Bowl Flls, P. Adshead Aug., 1961, (Alta); Jasper N.P., Whistlers Mt. 175-7, 175-9, 175-10, 176-2, 176-8, 176-10, (Alta); Jasper N.P., Mount Edith Cavell, MO 226-7, 226-8, 226-11, 226-12, (Alta); Jasper N.P., Old Fort Point, MO 273-6, 272-7, (Alta); Jasper N.P., Athabasca Falls, MO 274-5, (Alta); Jasper N.P., Jonas Creek, MO 233-3, 233-9, 233-10, (Alta); Jasper N.P., Wilcox Peak, MO 234-2, 234-3, 238-2, 238-3, 238-4, (Alta); Jasper N.P., Parker Ridge, MO 235-3, 235-4, 235-7, 236-1-1, 236-3, 236-4, 236-6, (Alta); Banff N.P., Cirrus Mt. MO 238a-1, 238a-5, 238a-6, 238a-7, (Alta); Banff N.P., Waterfowl Lakes, MO 239-2, (Alta); Banff N.P., Cirque Lake, C.E. Beil

64, 72, (U Calgary); Banff N.P., Sundance Canyon, MO 241-3-2, 241-4, 241-5, 241-6, 241-8, 241-10, (Alta); Banff N.P., Cascade Mt., C.E. Beil 3, (U Calgary); Banff N.P., Banff, P. Stringer June 10, 1965, (U Calgary); Banff N.P., Goat Creek, C.E. Beil, 345, (U Calgary); Banff N.P., Lake Louise, MO 243-3, 243-6, 244-1, 244-3, 245-1, 245-2, 245-4, 245-5, 246-2, (Alta); Banff N.P., Moraine Lake, MO 252-9, 252-10, 252-11, 271, 5, 271-6, (Alta); Banff N.P., Larch Valley, MO 269-5, 269-6, (Alta); Banff N.P., Sentinel Pass, MO 270-3, 270-4, (Alta); Waiparous Creek, CDB&G 13250a, 13252, 13296, 13304, 13362a, (U Calgary); Ghost Ranger Station, CDB&G 11256, 11283, 11285, 11320, (U Calgary); Devils Head Mt., CDB&G 12815, (U Calgary); Morley, CDB&G 13995, 14040a, (Alta); Ghost Dam, CDB&L 14475, (U Calgary); Calgary, CDB&L 14516, (U Calgary); Seebe, CDB&G 11053, 11054, 11058, 11061, 11072, 13706a, (U Calgary); Kananaskis, CDB&G 11012, (U Calgary); Kananaskis Lakes, CDB&G 12974, 13053, 13902, 13913, 13071, (U Calgary); Turner Valley, CDB&G 11484, 11540, (U Calgary); Elbow Lake, CDB&G 13550a, (U Calgary); Highwood Pass, CDB&G 13617, (U Calgary); Gorge Creek, CDB&G 11950, 11975, 11982, 12002, (U Calgary); Moose Mt., CDB 8831, (U Calgary); Bragg Creek, CDB&S 9258, (U Calgary); Bragg Creek, CDB&G 12061, 12110, 12219, 12233, (U Calgary); Little Elbow River, CDB&G 12318, (U Calgary); Highwood Ranger Station, CDB&G 12478a, 12490, 12556, 12590, 12709, 14050, 14199, (U Calgary); Hailstone Butte, CDB&L 15631a, (U Calgary); Plateau Mt., CDB 9220, (U Calgary); Straight Creek, W.W. Jeffrey Aug. 7, 1962, (U Calgary); Mount Erris, CDB&L 15741, (U Calgary); Gould Dome, CDB&L 15770, (U Calgary); Gap Ranger Station, CDB&L 15867, 15880, (U Calgary); Porcupine Hills, CDB&L 14613, 14649, 14669, 14719, (U Calgary); Pincher Creek, CDB&L 14763, 14788, 14877, 14941, 14942, 14993, (U Calgary); Waterton Lakes N.P., Cameron Lake, MO 260-1,

260-9, (Alta); Waterton Lakes N.P., Mount Lineham, MO 261-1, 261-2, 261-3, 26104, 261-5, 261-6, 261-7, 261 9, 261-11, 261-12, 261-13, 261-16, 261-17, (Alta); Waterton Lakes N.P., Cameron Falls, GWS 774, (CWS); Waterton Lakes N.P., Chief Mt., MO 266-3, 266-4, 266-5, 266-6, 266-10, (Alta); Waterton Lakes N.P., Waterton, MO 263-2, 263-3, 263-4, 263-5, (Alta); Waterton Lakes N.P., Crandell Lake, CDB&L 15044a, 15056a, (U Calgary); Waterton Lakes N.P., Crandell Mt., MO 262-5, 262-6, 262-7, 262-8, 262-9, 262-10, 262-11, 262-12, 262-26, 262-27, 262-45, (Alta); Waterton Lakes N.P., Red Rock Canyon, LLK Aug. 11, 1961, (Alta); Waterton Lakes N.P., Red Rock Canyon, GWS 712, 717, 724, 729, 731, (CWS); Waterton Lakes N.P., Red Rock Canyon, MO 264-18, 264-19, 264-20, 264-21, 264-22, 264-23, (Alta); Waterton Lakes N.P., Blakiston Falls, MO 265-6, 265-7, 265-8, 265-9, (Alta); Cypress Hills, LLK 734-1, 734-2, 734-3, 734-4, 731, (Alta); Cypress Hills, A.J. Gilchrist July 27, 1965, (Alta); Cypress Hills, R.D. Newsome 27-61, 50-61, (U Calgary); Cypress Hills CDB 4752, (U Calgary).

BRITISH COLUMBIA: Yellowhead, MO 228-2, 228-6, (Alta); Mount Robson, MO 229-2-1, 229-3, 229-5, 230-1, (Alta); Yoho N.P., Takakkaw Falls, MO 248-2, 248-3, 249-3, 249-4, 249-5, (Alta); Fernie, MO 267-3, 267-4, (Alta); Dawson Creek, H.J. Brodie June r, 1966, (Alta); Vancouver Island, LLK 744, (Alta).

NORTHWEST TERRITORIES: GWS 1739, 1896, 2337, 2674, 2709, 2719, 2867, 3100, 3774, 3813, 4069, 4090, 4091, (CWS).

MANITOBA: CDB 8446, 8529, 8544, 8570, (U Calgary).

COLORADO: L. Wirth April 15, 1962, (U Calgary).

WYOMING: CDB 10897a, L. Wirth July 10, 1963, (U Calgary).

Peltigera canina var. ulorrhiza (Flk.) Schaer.

This variety is rare in Alberta. Thomson considers it intermediate between the varieties canina and rufescens, but as I have seen only three specimens I can make no comment.

Specimens Examined:

ALBERTA: Kananaskis Lakes, CDB&G 13153, (U Calgary).

SASKATCHEWAN: J. Looman 634906, (U Calgary).

COLORADO: S. Shushan sl-558, (U Calgary).

Peltigera canina var. spongiosa Tuck.

This variety is most easily recognized when growing on mosses in moist habitats. In dryer habitats the thallus is more closely appressed to the substrate and the growing together of the brush-like tips of the rhizines may be partially within the substrate and somewhat obscured.

Thomas regards this variety as having a northern distribution, just coming into the United States. In the Jasper-Hinton area in Alberta it occurs with about the same frequency as the variety rufescens and in similar habitats. Further south it becomes less frequent except for a resurgence in the Waterton area. This variety was not collected in the Rocky Mountain House area but many of the collections from there were intermediate between varieties spongiosa, rufescens and canina. Further investigation of the group might be centered profitably on this area.

Specimens Examined:

ALBERTA: Whitecourt, MO 254-5, 255-1, 255-2, 256-10, (Alta); Hondo, E.H. Moss 9900, 9901, (Alta); Elk Island N.P., MO 92, 93, (Alta); Muir Lake, E. Bozniak Sept. 14, 1965, (Alta); Hinton, LLK 734a-4, 735-1, 735-2, (Alta); Hinton, MO 173a, 173e, 173j, 173L, (Alta); Jasper N.P.,

Whistlers Mt., MO 175-4, 175-5, 176-1, 176-3, 176-4, 176-7, 176-9, (Alta); Jasper N.P., Mount Edith Cavell, MO 226-16, (Alta); Jasper N.P., Maligne Lake, MO 227-3-2, 227-4, 227-6, 227-7, 227-16, (Alta); Jasper N.P., Mount Tekarra, H.J. Brodie June 18, 1966, (Alta); Jasper N.P., Old Fort Point, MO 273-2, 273-3, 273-4, 273-4, (Alta); Jasper N.P., Athabasca Falls, MO 274-15, 274-16, 274-17, 274-18, 274-19, 274-20, (Alta); Jasper N.P., Jonas Creek, MO 233-6, (Alta); Banff N.P., Waterfowl Lakes, MO 239-1, 239-5-2, (Alta); Banff N.P., Larch Valley, MO 269-7, (Alta); Morley, S. Simpson 13, (U Calgary); Waterton Lakes N.P., Chief Mt., MO 266-8, (Alta); Waterton Lakes N.P., Crandell Mt., MO 262-4, 262-39, 262-40, 262-41, 262-47, (Alta); Waterton Lakes N.P., Blakiston Falls, MO 265-16, (Alta).

BRITISH COLUMBIA: Yellowhead, MO 228-7, (Alta); Mount Robson, MO 229-1, 229-4, (Alta); Yoho N.P., Emerald Lake, MO 247-2, (Alta); Kootenay N.P., McLeod Meadow, MO 268-1, 268-2, 268-4, 268-5, 268-6, (Alta); Fernie, MO 267-1, 267-2, (Alta).

NORTHWEST TERRITORIES: GWS 1520, 1894, (CWS).

Peltigera canina var. rufescens f. innovans (Korb.)

The use of squamules of "squamulose isidia" as a feature for distinguishing species has been investigated by Thomson (1948) in North America and Lindahl (1960) in Europe. Thomson concludes that the presence of squamules is of minor taxonomic character. The evidence offered by each is convincing and until a better understanding is reached of the relationship between the lichen and its environment the two points of view must remain unreconciled.

In those specimens which I have seen, the abundance of squamules is variable from one or two on a thallus to so numerous and well developed

that they can be seen without magnification.

It is of interest to note that the distribution patterns of forms with squamules are similar in Alberta. These forms are Peltigera canina var. rufescens f. innovans, P. polydactyla var. microphylla and P. horizontalis var. horizontalis f. zopfi. Perhaps Peltigera evansiana with cylindrical isidia should also be included. This similarity in response from at least two clearly distinct groups, Peltigera canina and P. polydactyla, suggests the possibility of a common factor eliciting this response. But, it is not clear from existing information whether the potential to produce squamules is present in all members of the two species and becomes evident only under particular conditions, or whether this potential is restricted to some members whose range is determined by climatic or other factors.

Edmonton appears to be a focal point in the distribution of forms with squamules as some of the more abundantly squamulose collections were made within the city limits.

Specimens Examined:

ALBERTA: Whitecourt, MO 256-7, (Alta); Elk Island N.P., MO 77, 78, (Alta); Edmonton, MO 3, 4, 6, 7, (Alta); Waterton Lakes, N.P., Cameron Lake, MO 260-10, (Alta); Waterton Lakes N.P., Mount Lineham, MO 261-10, 261-14, 261-15, (Alta); Waterton Lakes N.P., Waterton. MO 263-9, 263-10, (Alta); Waterton Lakes N.P. Grandell Mt., 262-23, (Alta); Waterton Lakes N.P., Red Rock Canyon, MO 264-33, (Alta).

BRITISH COLUMBIA: Fernie, MO 267-7, (Alta).

Peltigera canina (L.) Willd. var. canina f. sorediata (Boist.)

The lobes of this form are usually small, 4 - 8 cm across, rounded distinctly cup shaped and with patches of gray soredia within the cup.

When on fire-mosses (Ceratodon, Funaria, Tortula.) the lobes are frequently scattered and sunken into the substrate. From this distinctive shape the form sorediata grades into the shapes more usual for small members of the varieties canina, rufescens and spongiosa. This form has been collected most often in places where regeneration is following a burn and this is in agreement with Thomson's observations that it is a growth stage and not the distinct species, Peltigera erumpens which is characterised by soredia in patches on the upper surface. Thomson regards Peltigera erumpens as synonymous with Peltigera canina var. spuria f. sorediata.

I have not recognized Peltigera canina var. spuria as a distinct variety but rather have identified collections fitting its description as depauperate members of the Peltigera canina varieties rufescens, canina and spongiosa. I believe that the sorediate form is worthy of recognition as a form, and since collection of the sorediate form are predominantly with the light under surface they have been included in the variety canina.

Specimens Examined:

ALBERTA: Crimson Lake, MO 171, 172, (Alta); Whitecourt, MO 254-10, 255-5, 255-7, 255-9, 255-10, (Alta); Elk Island N.P., MO 78a, 79, 81a, 82, 90, 91, (Alta); Miquelon Lakes MO 313, (Alta); Devon, MO 94, 95, 96, 97, 98, 99, 101, 102, 104-1, 111-1, (Alta); Carrot Creek, MO 275-3, 275-4, 275-5, (Alta); Jasper N.P., Old Fort Point, MO 273-1, (Alta); Jasper N.P., Athabasca Falls, MO 274-6, (Alta); Banff N.P., Lake Louise, MO 245-8, (Alta); Canmore, CDB&G 11413, (U Calgary); Morley, G. Holeton 26a, (U Calgary); Highwood Ranger Station, CDB&G 14089, (U Calgary); Forgetmenot Mt., CDB&G 14232a, (U Calgary); Turner Valley, CDB&G 11516, (U Calgary); Waterton Lakes N.P., Chief Mt., MO 266-7, (Alta); Waterton Lakes N.P., Red Rock Canyon, MO 264-32, (Alta); Waterton Lakes N.P., Blakiston Falls,

MO 265-15, (Alta).

BRITISH COLUMBIA: Mount Robson, MO 228-3, 230-5, (Alta); Yoho N.P., Takakkaw Falls, MO 249-7, (Alta); Fernie, MO 267-8, (Alta).

NORTHWEST TERRITORIES: GWS 1503, 1521, 1623, 1937, 2180, 2184, 2377, (CWS).

Peltigera evansiana Gyel.

Thomson regards this species as distinct from Peltigera canina on the basis of the cylindrical isidia which occur scattered over the upper surface and are not particularly associated with cracks or wounds in the thallus. Otherwise, it is similar to the medium sized members of Peltigera canina in shape and other characters but is often a uniform brown in color.

The occurrence of this species in the same part of Alberta from which squamuled forms of other species have been collected has been commented upon in connection with Peltigera canina var. rufescens f. innovans.

One collection from Edmonton, (MO 7, (Alta)), has abundant cylindrical isidia and stages in squamule development occurring together over the surface of the lobes. In this case the cylindrical isidia were taken as the more important feature and the collection classified as Peltigera evansiana.

This species has not been collected outside the Edmonton area in Alberta.

Specimens Examined:

ALBERTA: Elk Island N.P., MO 88, 89, (Alta); Edmonton, GWS 693, (CWS); Edmonton, MO 7, (Alta); Fort Saskatchewan, G.H. Turner 11218, (U Calgary).

WISCONSIN: H. A. Sierk 2836, (U Calgary).

Peltigera horizontalis (Huds.) Baumg.

Thallus usually 5 - 20 cm, but ranges from 1 to over 30 cm across, lobes usually imbricated, 1.5 - 3 cm broad and 2 - 3 cm long but ranging from 1 - 4 cm broad and 1 - 5 cm long; margins ascending and involute, smooth to crisped. Thallus shape usually indefinite. Upper surface smooth to semi-glossy, tomentum lacking, occasionally whitish pulverulent at the tips of the lobes, sometimes with squamules bordering cracks, wounds or at the margins of the lobes. Color, bluish gray, brownish gray or brown when dry, darker and with greenish tones when moist. Under surface with an indefinite network of broad, dark veins, sometimes so broad that only a few white interspaces are evident. Rhizines usually sparse, fasciculate and dark in color.

Cortex pseudo-parenchymatous, hyaline to brown, 40 - 60 μ thick. Algal zone continuous, 60 - 80 μ thick; algae of the thallus Cyanophyta (Nostocaceae), 5 - 9 μ in diameter. Medulla 300 - 600 μ thick, of very loosely interwoven hyphae, 12 μ in diameter with a lumen of 9 μ .

Apothecia 3 - 6 mm in diameter but up to 12 mm, oriented horizontally at the edge of the lobes or on short lobules, the disc chestnut brown, the margin crenate, the reverse with scattered patches of cortex. Hypothecium pale brown, hymenium hyaline below, brown above, paraphyses simple, thickened and darkened at the tips; asci cylindrico-clavate, 60 x 10 μ , 8-spored, spores fusiform, 3-septate, 24 - 48 x 3.5 - 7.5 μ .

Reactions: K negative, C negative, KC negative, P negative, I stains asci blue, GE lipid positive, crystal positive.

Habitat: On litter, rotting logs and stumps, on soil and rocks, on or with mosses; in moist woods.

Comments: Peltigera horizontalis and P. polydactyla are quite similar except for the apothecia. Without these they cannot be distinguished.

The broad veins, total lack of tomentum and the usually blue gray or slaty gray color of dry material serve to distinguish Peltigera horizontalis and P. polydactyla from other species. In some instances, however, close examination is needed to distinguish between these species and Peltigera malacea.

Thomson recognizes six forms in the species. In the material I studied two of these forms were distinguished.

Key to the Varieties and Forms of Peltigera horizontalis

1. Lobes with squamules bordering cracks, wounds or at margins ---
P. horizontalis var. horizontalis f. zopfi.
1. Lobes with smooth margins and smooth borders to cracks or wounds ---
P. horizontalis var. horizontalis.

Peltigera horizontalis (Huds.) Baumg. var. horizontalis

There is some indication that, although the range of this variety extends into the mountains, it is probably better regarded as a parkland and mixed forest variety.

Specimens Examined:

ALBERTA: Hondo, E.H. Moss 9901a, (Alta); Edmonton, GWS 669, 671, (CWS); Spruce Grove, LLK 15/10/56, (Alta); Hinton, GWS 829, (CWS); Jasper N.P. Old Fort Point, GWS 855, 857, (CWS); Banff N.P., Cascade Mt., C.E. Beil 40, (U Calgary); Waiparous Creek, CDB&G 13251, (U Calgary); Canmore, CDB&G 12928, (U Calgary); Seebe, CDB&G 11039, 13706, (U Calgary); Morley, CDB&G 13979, 14040, (U Calgary); Spray Lake, CDB&G 13191, (U Calgary); Kananaskis Lakes CDB&G 13921, (U Calgary); Elbow Lake, CDB&G 13559, (U

Calgary); Highwood River, CDB&G 12556, 12618, 12662, (U Calgary).

NORTHWEST TERRITORIES: GWS 2982, (CWS).

Peltiger horizontalis (Huds.) Baumg. var. horizontalis

f. zopfi (Gyel.)

Some aspects of the distribution of this form have been discussed in connection with P. canina var. rufescens f. innovans.

In view of the uncertain significance of the squamules, this form is retained as distinct from the variety.

Specimens Examined:

ALBERTA: Whitecourt, MO 256-13, (Alta); Miquelon Lakes, MO 212, (Alta); Obed, P. Seymour July 10, 1965, (Alta); Entrance Prov. Park, LLK 736-1, 736-2, (Alta); Hinton, MO 173b, 173h, (Alta).

Peltigera lepidophora (Nyl.) Vainio

One collection, (Nose Hill, E.H. Moss 1598, (Alta)), appears to agree with the description given by Thomson. The collection is, however, rather small and aged. It was not possible to establish with certainty whether the algae in the peltate isidia were of the same type as in the thallus (Nostocaceae) as is characteristic for the species, or whether they belonged to the Chlorophyta which would suggest that the 'peltate isidia' might be primary thalli of a Cladonia. Instances of Cladonia becoming established on mosses or other lichens are not uncommon and in sizeable collections present no difficulties.

Peltigera malacea (Ach.) Funck.

Thallus usually 5 - 15 cm, but ranges from 3 - 20 cm across, lobes usually 2 - 3 cm broad and 2 - 4 cm long but ranging from 1 - 4 cm broad

and 1 - 8 cm long. Margins involute, exposing the under surface as a light border to the lobes; smooth to moderately crisped. Thallus shape indefinite, sometimes rosette-like. Upper surface smooth and semi-glossy to dull in the center; tomentum at the margins erect to irregular webby or sub-erect, moderately abundant to very sparse, sometimes also whitish pulverulent toward the tips of the lobes. Color, dull dark brown, brownish gray to light bluish gray when dry, becoming darker, dull green to bright green when moist. Under surface without veins and covered with a fine even nap, dirty white to tan at the margin, blackish-brown to the center, sometimes with a few sunken whitish areas resembling vein interspaces. Rhizines fasciculate, black and usually sparse.

Cortex pseudo-parenchymatous, hyaline to brown, 25 - 50 μ thick. Algal zone continuous, 35 - 50 μ thick. Algae of the thallus Cyanophyta (Nostocaceae), 4 - 8 μ in diameter. Medulla 450 - 1800 μ thick, of exceedingly loosely interwoven hyphae, 10 μ in diameter with a lumen of 7 μ .

Apothecia 4 - 8 mm in diameter, on extended lobules, the sides reflexed, the margin crenate; disc chestnut to blackish brown, paraphyses simple, thickened and darkened at the tips to a red-brown; asci cylindric-clavate, 80 x 12 μ , 8-spored, the spores acicular, 3 - 5 septate, hyaline, 46 - 72 x 3.5 - 6 μ .

Reactions: K negative, C negative, KC negative, P negative, I stains the asci blue, GE lipid positive, crystal positive.

Habitat: On litter, soil, mosses, in habitats ranging from exposed sandy ridges to moist woodland with feather mosses.

Collections from the more moist habitats are easily recognized through the bristly tomentum and absence of veins. Collections from the

dryer habitats often have little tomentum and this can be only vaguely erect or largely obscured by a pruina-like encrustation at the tips of the lobes. Also, such specimens frequently have apparent vein interspaces which are light colored. An isolated specimen with scant tomentum could be easily placed as Peltigera polydactyla var. crassiodes. Some collections from Waterton were of this nature, but by examining a large number of specimens a series could be constructed of lobes having no tomentum through to lobes having clear indications of erect tomentum. This series when combined with a similar one for a group of collections from a sandy exposed site at Whitecourt extended the range of this feature through to what is 'typical' for Peltigera malacea.

In view of the fact that the south-west corner of Alberta has a number of vascular plant species which do not occur elsewhere in Alberta (Moss 1944) it is not unreasonable to suppose that distinct lichen species might also occur there and not elsewhere in Alberta. For this reason a series using specimens from Waterton and Whitecourt is perhaps open to question. However, a similar series can be constructed from a group of Peltigera canina collections made within a few yards of each other at Waterton.

On the basis of these observations I think that the etomentose, or nearly so, forms of Peltigera canina and Peltigera malacea represent extremes in the expression of this character which should be included in the existing categories. To this end I have expanded Thomson's descriptions of Peltigera canina and Peltigera malacea to fully accommodate these extremes.

Specimens Examined:

ALBERTA: Crimson Lake, MO 161, 162, (Alta); Whitecourt, MO 257-1, 257-2,

257-3, 257-5, 257-7, 257-9, 254-9, (Alta); Moose Lake, A.J. Gilchrist July, 1965, (Alta); Jasper N.P., Mount Edith Cavell, MO 226-1, 226-2, 226-13, (Alta); Jasper N.P., Maligne Lake, MO 227-1-1, 227-5, (Alta); Jasper N.P., Tangle Ridge, C.E. Beil 211, (U Calgary); Jasper N.P., Jonas Creek, MO 233-2, (Alta); Banff N.P., Lake Louise, MO 243-5, (Alta); Banff N.P., Moraine Lake, MO 271-1, (Alta); Banff N.P., Larch Valley, MO 269-8, 269-9, 269-10 (Alta); Wiaparous Creek, CDB&G 13405, (U Calgary); Barrier Reservoir, CDB&G 13811b, (U Calgary); Gorge Creek, CDB&G 11963A, (U Calgary); Bragg Creek, CDB&G 12218, (U Calgary); Highwood River, CDB&G 12478, (U Calgary); Turner Valley, CDB&G 11826, (U Calgary); Millarville, CDB&G 14232b, (U Calgary); Hailstone Butte, CDB&L 15631, 15692a, (U Calgary); Mount Erris, CDB&L 15742a, 15752a, (U Calgary); Pincher Creek, CDB&L 14763a, (U Calgary); Waterton Lakes N.P., Cameron Lake, MO 269-2, 260-3, (Alta); Waterton Lakes N.P., Crandell Lake, CDB&L 15044, (U Calgary); Waterton Lakes N.P., Crandell Mt., MO 262-43, 262-46, 262-49, (Alta); Waterton Lakes N.P., Red Rock Canyon, MO 264-6, 264-7, 264-8, 264-9, 264-10, (Alta); Waterton Lakes N.P. Blakiston Falls, MO 265-10, 265-11, 265-12, 265-13, 265-14, (Alta).

NORTHWEST TERRITORIES: GWS 1481, 1492, 1586, 1729, 1755, 1761, 1838, 1962, 2142, 2194, 2222, 2395, 2562, 2687, 2781, 2873, 3000, 3817, 3820, 4038, (CWS).

COLORADO: CDB 10848, S. Shushan s1-556, (U Calgary).

Peltigera membranacea (Ach.) Nyl.

This species is separated from Peltigera canina on the basis of a very thin medulla (70 - 110 μ), narrow and sharply defined veins, slender rhizines up to 1 cm long which are simple and covered with a fine, even and erect nap that may also occur on the veins. Because of the thinness

of the medulla the vein interspaces often have a decidedly greenish coloration.

No collections of this species were made in Alberta during this study and its occurrence here has not been verified. The reported P. membranacea from the Lesser Slave Lake Area (Moss 1953) appears to have been based on a mis-determination of Peltigera canina var. spongiosa (Hondo, E.H. Moss 9900, 9901, (Alta)). The only other collection, reported in Thomson, (Marion Lake, Lesser Slave District, Brinkman 1928, (U.S. Dept. of Agriculture, Beltsville, Maryland)), has not been seen.

Present information indicated that this species does not occur in the study area.

Specimens Examined:

BRITISH COLUMBIA: Vancouver Island, LLK 738, 739, (Alta); Vancouver Island, CDB 15545, (U Calgary); Vancouver Island, R.D. & L. Bird 43, (U Calgary).

Peltigera polydactyla (Neck.) Hoffm.

Thallus usually 5 - 30 cm, but ranges from 1 cm to about 800 cm across, lobes usually imbricated, 2 - 3 cm broad and 2 - 3 cm long but ranging from 1 - 4 cm broad and 1 - 5 cm long. Margins ascending and involute, smooth to crisped. Upper surface smooth to semi-glossy, sometimes slightly scabrid or dull, tomentum lacking, occasionally whitish pulverulent at the tips of the lobes. Sometimes with squamules bordering cracks, wounds or at the margins of the lobes. Color bluish gray, brownish gray or brown when dry, darker and with greenish tones when moist. Under surface with an indefinite network of broad dark veins, sometimes so broad that only a few white interspaces remain. Rhizines usually sparse, fasciculate and dark.

Cortex pseudo-parenchymatous, hyaline to brown, about 30 μ thick. Algal zone continuous, 20 - 30 μ thick; algae of the thallus Cyanophyta (Nostocaceae), 3 - 6 μ in diameter. Medulla 200 - 700 μ thick, of very loosely interwoven hyphae, 8 μ in diameter with a lumen of 5 μ .

Apothecia 2 - 5 mm in diameter on erect narrow lobules at the ascendant tips of the lobes, sometimes borne in pairs, the sides usually reflexed, the disc reddish or chestnut brown to black, the margins crenate, the reverse corticate; hypothecium brown, hymenium hyaline, paraphyses thickened and darkened at the tips, asci cylindrico-clavate, 80 - 105 x 10 μ , 8-spored; spores acicular, 3 - 7-septate, 48 - 105 x 3 - 4 μ .

Reactions: K negative, C negative, KC negative, P negative, I stains the asci blue, GE lipid positive, crystal positive.

Habitat: On litter, rotting logs and stumps, on soil and rocks with or on mosses; in moist woods.

Comments: The similarity between Peltigera polydactyla and Peltigera horizontalis has been mentioned in connection with the latter species: without apothecia the two cannot be distinguished.

There are some indications that Peltigera polydactyla occurs more frequently in the mountains than Peltigera horizontalis, though it too might be regarded as a species of the mixed woods and parkland.

Collections from the Cypress Hills have included both the smooth form and the form with squamules. However, lack of apothecia has prevented placing these as either Peltigera polydactyla or Peltigera horizontalis.

Key to the Varieties and Forms of Peltigera polydactyla.

1. Lobes with squamules bordering cracks, wounds or at margins ---
P. polydactyla var. polydactyla f. microphylla.
1. Lobes with smooth margins and smooth borders to cracks or wounds --- 2.

2. Vein interspaces conspicuous --- P. polydactyla var. polydactyla.

2. Vein interspaces inconspicuous --- P. polydactyla var. crassoides.

Thomson lists six varieties or forms for this species. All Alberta collections were classified as the variety polydactyla.

The variety crassoides is included here to draw attention to the similarity between it and some collections of Peltigera malacea. The total lack of tomentum in Peltigera polydactyla and the presence of at least a trace of tomentum at the tips of the lobes in Peltigera malacea distinguishes these species.

Peltigera polydactyla (Neck.) Hoffm. var. polydactyla

Specimens Examined:

ALBERTA: Crimson Lake, MO 128, 139-2, 142-2, (Alta); Whitecourt, MO 256-2-2, (Alta); Elk Island N.P., MO 253, (Alta); Elk Island N.P. GWS 629, (CWS); Miquelon Lakes, MO 208-2, 258-3, (Alta); Hay Lakes, LLK Aug. 17, 1961, (Alta); Edmonton, LLK Sept. 10, 1961, (Alta); Wabamun, MO 259-1, 259-2, 259-3, 259-6, 259-10, (Alta); Muir Lake, E. Bozniak Sept. 14, 1965, (Alta); Carrot Creek, MO 275-7, 275-8, 275-9, (Alta); Hinton, J. Stelfox July 16, 1959, (Alta); Jasper N.P., Whistlers Mt., MO 175-2, (Alta); Jasper N.P., Old Fort Point, MO 273-8, 273-9, (Alta); Jasper N.P., Athabasca Falls, MO 274-11, 274-12, 274-13, 274-15, (Alta); Jasper N.P., Old Fort Point, GWS 864, (CWS); Banff N.P., Lake Louise, MO 246-4, (Alta); Ghost Ranger Station, CDB&G 11256b, (U Calgary); Gorge Creek CDB&G 11963, 12019, (U Calgary); Turner Valley, CDB&G 11483, 11546, (U Calgary); Porcupine Hills, CDB&L 14649a, 14669a, (U Calgary); Mount Erris, CDB&L 15752, (U Calgary).

BRITISH COLUMBIA: Yoho N.P., Takakkaw Falls, MO 248-1, (Alta); Kootenay N.P., McLeod Meadow, MO 268-14, (Alta); Vancouver Island, LLK 740, (Alta);

Vancouver Island, R.D. & L. Bird 70, (U Calgary).

NORTHWEST TERRITORIES: GWS 1794, 1975, 3756, 4095, 4361, (CWS).

SASKATCHEWAN: J. Looman 620108, (U Calgary).

NOVA SCOTIA: GWS 8:6298, (U Calgary).

ARIZONA: H. A. Sierk 2353, (U Calgary).

COLORADO: H. A. Sierk 2475, (U Calgary).

OREGON: S. Shushan sl-2094, (U Calgary).

Peltigera polydactyla (Neck.) Hoffm. var. polydactyla
f. microphylla Thomson.

The distribution of this form is similar to that of Peltigera horizontalis var. horizontalis f. zopfi which it resembles closely.

Because of the apparently restricted distribution and uncertain significance of the squamules both forms have been recognized.

Specimens Examined:

ALBERTA: Nordeg, J. Wheelock W4, (Alta); Whitecourt, MO 256-12, (Alta); Miquelon Lakes, MO 207, (Alta); Edmonton, MO 276-1, 276-2, 276-3, (Alta); Entrance Prov. Park, LLK 734a-5, 735-3, (Alta).

Peltigera pulverulenta (Tayl.) Nyl.

Thallus usually 20 - 30 cm across, lobes usually 3 - 4 cm broad and 5 - 7 cm long, but up to 6 cm broad and 10 cm long; marginal region involute, the margins sometimes becoming revolute. Upper surface dull, scabrid to somewhat lustrous; tomentum lacking or present as a loose, webby tomentum, often patchy, toward the tips of the lobes. Color a light silvery gray, greenish gray, yellowish brown to brown when dry, becoming much darker and with greenish tones when moist. Under surface with white to dark veins, the veins an irregular network of broad and indefinite ones

together with narrow sharply raised ones; the interspaces light, often deep, the hyphae of the interspaces and veins evident under low magnification (x 10) as forming a very loose, irregular network in the interspaces but grading smoothly into the veins where orientation in the direction of the vein is clear and the hyphae more compactly arranged. Rhizines fasciculate, often velutinate, sometimes forming a thick mat to the center of the thallus, light to dark brown and sparse to abundant.

Cortex pseudo-parenchymatous, hyaline to brown, 50 - 70 μ thick. Algal zone continuous, 40 - 75 μ thick; algae of the thallus Cyanophyta (Nostocaceae), 6 - 10 μ in diameter. Medulla 50 - 600 μ thick, of loosely interwoven hyphae, 11 μ in diameter with a lumen of 4 μ .

Apothecia up to 6 mm across, on extended lobules, rounded or with the sides reflexed, the margin entire, the reverse corticate; disc dark reddish-brown; hypothecium hyaline to pale brown, hymenium hyaline; paraphyses simple, thickened and dark red brown at the tips; asci cylindrico-clavate, 10 x 105 μ , 8-spored, spores acicular, 5 - 7-septate, 60 - 100 x 2 - 4 μ .

Reactions: GE lipid positive, crystal positive.

Habitat: On soil and mosses.

Comments: In his monograph Thomson lists this species as Peltigera scabrosa T. Fr. In a more recent article, Thomson (1955) indicates that Peltigera pulverulenta (Tayl.) Nyl. takes precedence.

The collections from Alberta and British Columbia have all been from moist locations and in association with feather mosses. Whether this is due to chance or to the species having a narrow range of tolerance to environmental factors is not known.

Peltigera pulverulenta had not been reported from Alberta because

collections of this species had been identified as Peltigera canina. The two species can be indistinguishable on the basis of general appearance and features of the upper surface. However, the character of the under surface of each species is quite different. Under low magnification, (x 10), Peltigera canina has hyphae which are compactly interwoven to the extent that the individual hyphae are often indistinguishable. Peltigera puerulenta, on the other hand, has loosely interwoven hyphae and the individual hyphae are easily seen or even obvious. The general appearance of the underside of Peltigera pulverulenta under low magnification suggests the textural quality of candy floss (Figures 12, 13, page 62).

The chemistry of the two species differs. Peltigera pulverulenta yields crystals in GE, Peltigera canina does not. In addition, in Peltigera pulverulenta the medullary hyphae, particularly those just below the algal zone, have rough walls whereas in Peltigera canina the walls of these hyphae are smooth.

These observations lead me to conclude that features of the upper surface are not satisfactory for defining this species. Just as with Peltigera canina and Peltigera malacea a series can be constructed for P. pulverulenta which will include lobes with tomentum, through scabrid lobes to lobes which are smooth or semi-glossy.

Specimens Examined:

ALBERTA: Crimson Lake, MO 160, (Alta); Nordeg, J. Wheelock W1, (Alta); Whitecourt, MO 257-12, (Alta); Jasper N.P., Mount Edith Cavell, P. Seymour July 17, 1965, (Alta); Banff N.P., Sundance Canyon, MO 241-11, (Alta).

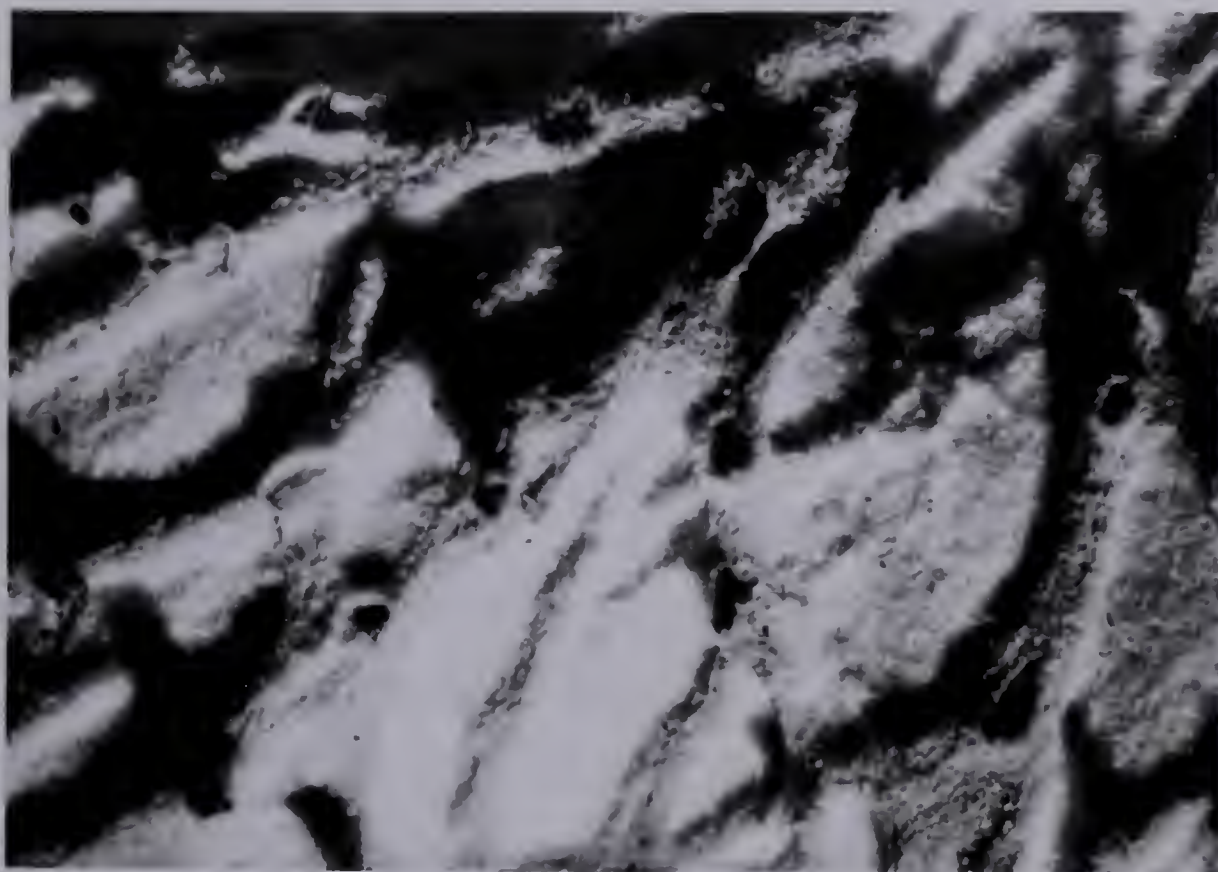
BRITISH COLUMBIA: Kootenay N.P., Paint Pots, MO 246a-2, (Alta).

NORTHWEST TERRITORIES: GWS 1970, 2181, 3081, (CWS).

Figure 12. Under surface of Peltigera canina. Note the uniformly felty quality. The dark spots on the veins are scars of rhizines removed to expose the under surface (x 30).

Figure 13. Under surface of Peltigera pulverulenta. The open, somewhat stringy quality of the under surface is evident here (x 30).

12



13



Peltigera scutata (Dicks.) Duby

The presence of this species in Alberta is based on the one collection from Banff reported by Thomson. I have seen no material from the study area which could be identified as this species.

Peltigera venosa (L.) Baumg.

Thallus of scattered lobes, lobes fan shaped, usually 0.8 - 1.5 cm but up to 2 cm across. Margins flat or only slightly ascending. Upper surface smooth and shining to dull. Color light gray-green to brownish gray when dry, bright apple green to brownish-green when moist. Under surface light with prominent veins, usually dark brown to black. Gray warty cephalodia on the veins usually obscure. Rhizines as a single off-center cluster on the under surface of the lobe, dark.

Cortex pseudo-parenchymatous, hyaline to brown, 40 - 60 μ thick. Algal zone continuous, 50 - 65 μ thick, algal cells of the thallus Chlorophyta (Palmellaceae), 2 - 3 μ in diameter; algal cells of the cephalodia Cyanophyta (Nostocaceae), 4 - 6 μ in diameter. Medulla 150 - 300 μ thick, of very loosely interwoven hyphae 6 μ in diameter with a lumen of 2.5 μ .

Apothecia usually 2 - 4 mm but up to 5 mm across, round, horizontal at the margins of lobes; the disc blackish brown to reddish brown, hypothecium pale to dark brown, hymenium hyaline to pale brown, paraphyses simple, thickened and darkened to a red-brown at the tips; asci cylindrico-clavate, 75 x 11 μ , 8-spored, the spores fusiform, 1 - 5-septate, 24 - 45 x 6 - 10 μ .

Reactions: K negative, C negative, KC negative, P negative, I stains asci blue, GE lipid positive, crystal positive.

Habitat: On mineral soils; moist cliffs, along edges of paths,

exposed mineral soil at base of uprooted trees.

Comments: The small size, bright green color, dark, horizontal and circular apothecia, together with the prominent veins makes this an easily recognized species. In addition, it is much less variable than the other species.

No collections of Peltigera venosa were made outside the mountain areas where it occurs fairly regularly though not abundantly when moist conditions and a mineral soil are found.

Specimens Examined:

ALBERTA: Jasper N.P., Mount Edith Cavell, MO 226-15, (Alta); Banff N.P., Cirrus Mt., MO 238a-8, (Alta); Banff N.P., Sundance Canyon, MO 241-7-1, (Alta); Banff N.P., Lake Louise, MO 244-7, 245-3, (Alta); Banff N.P., Larch Valley, MO 269-3, (Alta); Banff N.P., Sentinel Pass, MO 270-6, (Alta); Wiaparcous Creek, CDB&G 13257, 13303, 13363, (U Calgary); Kananaskis Lakes, CDB&G 12967, 12976, 13474, 13841, 13854, (U Calgary); Gorge Creek, CDB 9118, (U Calgary); Elbow Lake, CDB&G 13608, (U Calgary); Barrier Reservoir, CDB&G 13812, (U Calgary); Moose Mt., CDB 8851, (U Calgary); Highwood River, CDB&G 12557, 12665, (U Calgary); Highwood Ranger Station, CDB&G 14191, (U Calgary); Sheep River, CDB&G 11822, (U Calgary); Mount Errie, CDB&L 15758, (U Calgary); Gap Ranger Station, CDB&L, (U Calgary); Waterton Lakes N.P., Cameron Lake, MO 260-11, (Alta); Waterton Lakes N.P., Waterton, E.H. Moss 10197, (Alta); Waterton Lakes N.P. Cameron Falls, GWS 53, (CWS); Waterton Lakes N.P., Crandell Lake, CDB&L 15044a, (U Calgary); Waterton Lakes N.P., Red Rock Canyon, GWS 718, (CWS).

BRITISH COLUMBIA: J. Dugle Aug. 5, 1963, (Alta); R.D. & L. Bird 46, (U Calgary).

COLORADO: H. A. Sierk 2474, Shushan and Anderson s25973, S. Shushan s1-178, (U Calgary).

Distribution

The maps shown in Figures 14 - 25, page 67, include that part of Alberta south of Lesser Slave Lake. Lack of collections from the northerly portions of the area outlined in the maps is the reason for these appearing blank. It is, however, expected that Peltigera species are common throughout much of this area. The southern and eastern portions, on the other hand, appear blank because no Peltigera species were found in this area with the exception of the Cypress Hills. A careful search was made for Peltigera in the Steeveville area but none was found even in habitats where ferns and liverworts were present.

Since each dot on the maps represents a collection an estimate of the relative abundance of the species can be made and it becomes evident that Peltigera canina var. rufescens is by far the most commonly and widely distributed variety. The maps also suggest that Peltigera venosa is not abundant and is restricted to the mountains and that Peltigera pulverulenta is scarce but with a much wider distribution.

However, collections were not quantitative and relative abundance of species and varieties should not be interpreted as more than an indication that significant patterns exist in the relative frequencies of the different species and varieties. It should be noted also that the clustering of dots in the Waterton Lakes area on some of the maps may in part reflect improved collecting techniques gained through a previous summer's work with Peltigera. Consequently, any comparisons of relative frequency between Waterton Lakes National Park collections and others

should be done with the realization that the Waterton Lakes National Park collections probably represent a better sample of the local lichen flora than do those collections made early in the study.

Figure 14, page 67, indicates points from which the species and forms with isidia or squamules were collected. Each letter represents a different taxonomic group and the numbers of a particular letter indicate the number of collections of that taxonomic group. The letter e represents Peltigera evansiana and there are four collections of this species, all from the Edmonton area; the letter i represents Peltigera canina var. rufescens f. innovans and there are seven collections of this form from the Edmonton area, one from Whitecourt and eight from Waterton Lakes National Park. Similarly, the letter m represents Peltigera polydactyla var. polydactyla f. microphylla and its distribution and z represents Peltigera horizontalis var. horizontalis f. zopfi and its distribution. It can be seen from Figure 25, page 68, that there is a tendency for the one species with isidia, Peltigera evansiana, and the three forms with squamules to be concentrated in the Edmonton area.

A squamuled form, either Peltigera polydactyla var. polydactyla f. microphylla or Peltigera horizontalis var. horizontalis f. zopfi was collected in the Cypress Hills but, because apothecia were not present, it was not possible to identify this collection as to species.

Figure 14. The circles indicate areas where major collections were made or which were searched for Peltigera.

Letters on the map of the study area indicate the following locations: E, Edmonton; WC, Whitecourt; J, Jasper; CL, Crimson Lake; B, Banff; C, Calgary; S, Steepleville; CH, Cypress Hills; WL, Waterton Lakes.

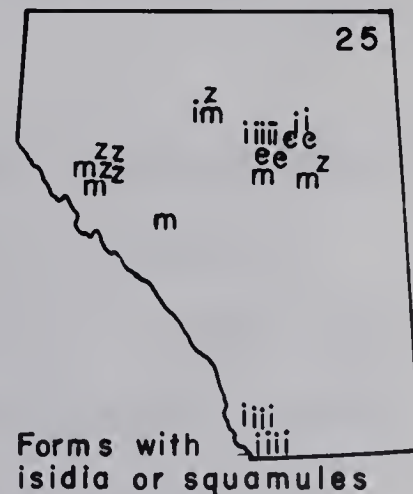
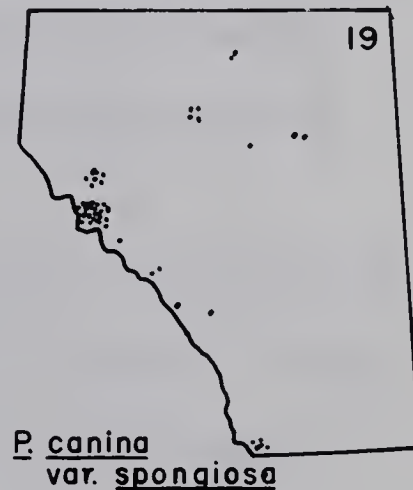
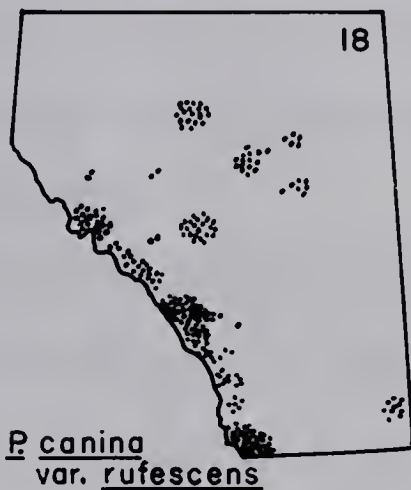
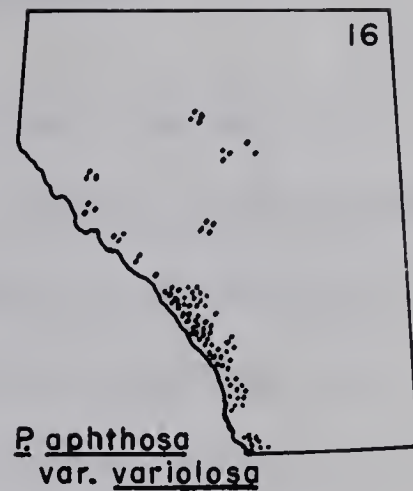
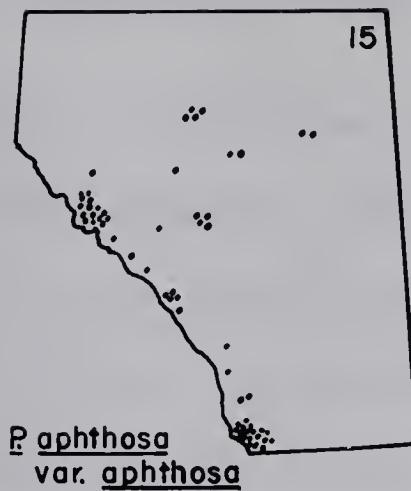
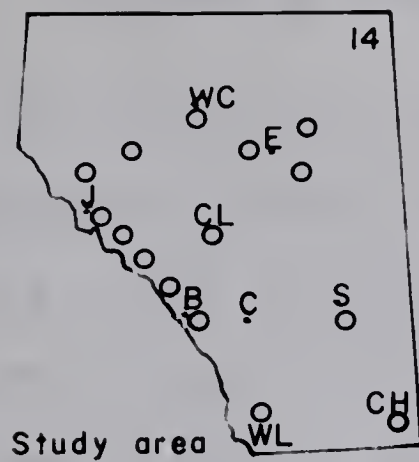
Figures 15 - 24. Distribution of Peltigera species and varieties.

Each dot represents a collection.

Figure 25. Distribution of forms with isidia or squamules.

Each letter represents a collection of one of the following taxa:

- i Peltigera canina var. rufescens f. innovans.
- e Peltigera evansiana.
- z Peltigera horizontalis var. horizontalis f. zopfi.
- m Peltigera polydactyla var. polydactyla f. microphylla.



A STUDY OF THE PELTIGERA CANINA COMPLEX

As was stated in the general introduction, lichen taxonomy rests upon morphological features whose expression under differing environmental conditions is virtually unknown. Weber (1962) showed that morphological features can vary greatly with changes in environmental conditions and, while he does not make the suggestion, his results indicate clearly that the development of techniques for critically analyzing morphological features of the lichen and relating them to the environment would be extremely useful in taxonomic studies.

There is no literature describing the simultaneous evaluation of morphological characters and environmental factors in lichens. Nor was any reference found to studies analyzing the effect of environmental factors on morphological characters in flowering plants.

The formulation of techniques suitable for analyzing as many morphological features as possible and relating them to a number of environmental features has been the object in this part of the study. Peltigera canina was selected for critical examination because it is a major component of the lichen flora in wooded areas and it is a highly variable and imperfectly understood species which is often difficult to identify.

There is a departure from the customary format in reporting on this study. It was thought that a presentation which attempted to follow the reasoning and the methods used in the approach to this study would result in a more coherent presentation than attempting to isolate the various aspects as introduction, literature review, methods and results. Therefore, the material presented in this section of the thesis

is organized in the following manner. First, a preliminary discussion of methods for analyzing morphological features of the thallus and relating them to the environment. Secondly, a detailed description of the polygonal graph method accompanied by examples of results obtained from applying this method to Peltigera canina specimens. Finally, a general discussion presented in the form of a summary.

Preliminary Discussion

It was considered that the most direct approach to combining taxonomic and ecological observations was to treat any given specimen and the environment in which it grew as a study unit. As a consequence the term 'character' or 'taxonomic character', which is restricted to mean a morphological attribute, is not applied to the study unit, but rather the term 'feature' is used. The study unit, that is a specimen of Peltigera canina and the environment of that particular specimen, can be described in terms of characteristics relating to the lichen together with those relating to the environment occupied by that lichen. The characteristics of both the lichen and its environment are referred to as features. The term can be qualified to refer only to the environmental aspect of the study unit (environmental features) or to refer only to the lichen of the study unit (morphological features). When reference is made to altitude as a feature of a specimen it simply means that the altitude is a part of that lichen in a sense, since it has a bearing on the existence and form of the lichen. In this concept the lichen is central and anything impinging upon it in any way is regarded as a feature of the lichen.

The central problem in analyzing morphological features of the lichen and relating them to the environment is how to deal with a number

of variables at the same time, and it seemed that methods used in analysis of hybrid populations in vascular plants offered considerable possibilities. Davis and Heywood (1963) describe a number of methods used for investigating the variability in hybrid populations and it was thought that some of these could be adapted to investigating the variability in Peltigera canina and its environment. It was decided early that graphical rather than statistical methods were preferable for exploratory purposes.

One such graphical method for investigating variability of morphological features is found in the pictorialized scatter diagrams and hybrid index graphs used by Anderson (1953), to examine populations of Oxytropis, Iris and other genera with complex variability. This method was also used by Anderson and Rudolph (1956) to investigate the variability in a population of the lichen Cladonia. It should be noted that, while the pattern of variation revealed in their study was similar to the pattern observed in hybrid populations of flowering plants, they are careful to point out that there is no genetical evidence which can confirm or deny the conclusion that this is a hybrid population.

Another graphical method which Löve and Nadeau (1961) suggest is more flexible than the pictorialized scatter diagram is the polygonal graph method of Hutchinson (1936), which has demonstrated its usefulness in analyzing the variability in the genus Xanthium. It has also been used in dealing with ecological data by Hutchinson (1940). Hutchinson used climatic data obtained by other workers studying the relationship between climatic factors and the distribution of vegetation. He plotted their data on radii to produce a polygonal figure which he called a bio-climatic graph. The bio-climatic graphs are based on the following factors as they occur during the frostless season: hours of sunlight,

length of frostless season, temperature, precipitation, evaporation and relative humidity. The resulting graphs are meant to represent a summation of the climatic factors occurring with different types of vegetation in the United States, for example, deciduous forest or grassland, and the graphs are clearly different for the climate occurring with the different vegetation types. From his work Hutchinson concludes that polygonal graphing of biotic, edaphic and climatic factors might provide a method for establishing standards for ecological classification, although in this work he has concerned himself only with the climatic factors. While Hutchinson uses climatic data for quite different purposes than those of this study, his results show that a complex of variable factors can be presented coherently using polygonal graphing. His results also indicate that polygonal graphs are not to be regarded as something which conveys its full meaning at a glance as many graphs are meant to do. The polygonal graph method as described by Davis and Heywood involves making up a "Key in the form of spokes radiating from a central point, the center being represented by a point or circle-shaped area. Each radius represents a single character, and distance along it expresses the variation of that character." By joining points on the radii, each point representing the value obtained for a particular feature, a polygonal figure results which represents pictorially those features, or characters, taken together. The polygonal graph method can deal with up to twelve features conveniently, but since more than twelve features were used at first in the present study, the modification of the polygonal graph method suggested by Davis and Heywood was tried.

In this modification the values for the different features are not plotted on radii but rather on lines standing erect to a base line. Each

of these lines has an index for the variation in one feature just as do the radii in the polygonal graph. However, any number of features can be used, for the base line with index lines standing upon it can be extended indefinitely. When the values obtained for the different features of a particular specimen are joined, a saw-toothed figure or graph results.

In preliminary work with the rectilinear version of the polygonal graph suggested by Davis and Heywood, specimens, chosen to include a wide range in habitat and morphological variation, were assessed for 38 features.

Features such as thickness of cortex and diameter of algal cells were measured and recorded in standard units. Others such as in-rolling of margins and cracking of thallus were scored in various ways to obtain a numerical expression for that feature. Details of scoring for the features finally used are described later but briefly, a feature was scored in such a way that one extreme of its expression received the lowest numerical value while the opposite extreme received the highest value.

Efforts were directed toward obtaining information about various aspects of the lichen in order that a broadly based understanding of the variation in morphological and environmental features might be obtained. The following list will serve to indicate in general terms the choice of features. Each group in the list represents from three to ten individual features.

Group 1. Size, shape, arrangement of lobes and condition of lobes as regards cracking.

Group 2. Features associated with the margin; folding, cracking, in-rolling and out-rolling.

- Group 3. Features of the undersurface; type of venation, color, condition and density of rhizines.
- Group 4. Features associated with the upper surface; whether it is smooth or cockled, amount of tomentum, presence and location of squamules and soredia.
- Group 5. Features of the habitat; moisture conditions, deciduous or coniferous woods, shading, type of substrate, altitude.
- Group 6. Chemical features; presence and amounts of oil, crystals and residue.
- Group 7. Microscopic features of the thallus; thickness of cortex, algal zone and medulla, diameter of algal cells, color of cortex and texture of medulla.

When the values obtained in preliminary work with the above list of features were plotted it was found that differences which could be observed when comparing two specimens visually were not clearly apparent in the graphical representation. In effect, it seemed that this method was defeating the purpose for which it was intended, that is to show clearly the relationship between morphological and environmental features. The inclusion of such a large number of features resulted in a graph that was too complex to grasp. Accordingly, it was decided to use the polygonal graph method and to plot only 12 features. The change was made from the saw-toothed to the polygonal type of graphic representation because it was found that a definite shape, such as a polygon, conveys a more concrete image than a line and hence is easier to comprehend. In addition, a polygon based on twelve radii can be related to positions on a clock face. Because of long familiarity with the positions on the clock one can compare the parts of the figure more easily than is the case

with an abstract line.

The same general consideration regarding choice of features mentioned earlier applied when working with only 12 features. That is, the aim was to draw information from as many aspects of the lichen as possible rather than to concentrate on only one or two aspects such as substrate and condition of the undersurface of the lichen. It is quite possible that a narrow approach involving study of one or two features would prove valuable, but exploratory work should be as broadly based as possible in order to locate areas where concentrated study can be best directed.

The decision to use only 12 features rather than a larger number was influenced by the comments of Löve and Nadeau (1961) and Davis and Heywood (1963). These workers suggest that 12 is about the maximum number of features which can be analyzed satisfactorily in the polygonal graph method. Since Peltigera canina is classified largely on the basis of vegetative characters most of the emphasis was placed on these in the scheme for analysis. Also, since less than two thirds of the Peltigera canina collections had apothecia emphasis on the thallus was unavoidable.

The Polygonal Graph Method

The following features were chosen for examination by the polygonal graph method:

1. Size of lobes.
2. Wrinkling or cockling of lobes.
3. Crisping of lobe margins.
4. Amount of tomentum.
5. Confluence of rhizines.
6. Amount of oil.
7. Amount of crystalline material.

8. Thickness of algal zone.
9. Thickness of cortex.
10. Color of cortex.
11. Quality of substrate.
12. Moisture conditions under which specimen grew.

These were evaluated as follows:

1. Size of lobes. A guide was made in the form of concentric circles drawn on clear acetate sheet. The diameters differed by 2 cm increments. This guide was laid over a specimen and the size of the circle just encompassing a lobe provided a measure of the size of the lobe, and was recorded as a size class.

<u>Diameter of circle</u>	<u>Size class of lobe</u>
4 cm	1
6	2
8	3
10	4
12	5
14	6

2. Cockling of lobes. The degree to which the lobes of a specimen were cockled or wrinkled was scored:

No cockling present	1
Cockling present	2
Markedly cockled	3

3. Crisping of lobe margins. Two features of the margin were combined to provide a value for crisping. The first is wavyness or folding of the margin and the approximate distances between wave crests established the score:

Part <u>A.</u>	<u>Crest to crest</u>	<u>Score</u>
	15 mm or more	1
	10	2
	7	3
	5	4
	3 mm or less	5

The second feature used to provide a value for crisping was the degree of inward rolling of the margin. This score was based on the prevailing tendency since the degree of in-rolling varies from place to place along the margin.

Part <u>B.</u>	<u>Degrees margin is rotated toward center of lobe</u>	<u>Score</u>
	0°	1
	45	2
	90	3
	135	4
	180	5

The value indicating the amount of crisping is the product of the score obtained in Part A multiplied by the score obtained in Part B.

4. Amount of tomentum on the upper surface of the thallus.

<u>Amount of tomentum</u>	<u>Score</u>
Slight	1
Moderate	2
Abundant	3

5. Condition of rhizines. The extent to which rhizines grow together to produce a spongy mat on the undersurface.

<u>Condition of rhizines</u>	<u>Score</u>
Free	1
Moderately entangled	2
Densely confluent	3

6 and 7. Amounts of oil and crystalline materials. These two factors were evaluated concurrently from the same microscopic preparation.

In order to obtain the preparation for these materials 3 discs 4 mm in diameter were cut with a cork borer from within 1 cm of the margin of a lobe. The discs were stacked on a microscope slide and 3 - 4 drops of acetone applied to produce a pool approximately 15 mm in diameter with the discs at the center. The acetone was allowed to evaporate to dryness. The addition of acetone followed by drying was repeated twice. The discs were removed, a drop of GE added, and a cover glass applied. The preparation was heated gently to the boiling point then allowed to cool and stand over night.

With one edge of the cover glass as reference, a traverse was made parallel with and 7 mm from that edge. Fields were counted at 4 mm intervals along the traverse, the first was about 2 mm from an edge of the cover glass at right angles to the reference edge. Fields were similarly located on a second parallel traverse 14 mm from the reference edge. This was repeated to give two additional traverses at right angles to the first two, and a total of twenty fields were counted. A magnification of x 500 was used and each field was scored as follows:

<u>Number of crystals or oil droplets</u>	<u>Score for one field</u>
None	0
Present	1
Few	2
Abundant	3

Oil droplets and crystals were scored separately and the scores for each were totalled from twenty fields to provide the final score for amount of oil and amount of crystalline material.

8, 9, and 10. Thickness of algal zone, thickness of cortex and color of cortex. Values for these features were obtained from microscopic cross sections of the thallus.

The preparations for evaluating these features were obtained by softening a portion of thallus in water for 10 - 15 minutes then orienting it in pith in such a way that sections were cut from the region which was 5 mm from and parallel with the margin at the tip of a lobe. The sections were cut with a straight razor, mounted in glycerol, a cover glass was applied and the preparation heated until frothy bubbles emerged from the sections. The slide was allowed to cool and the heating repeated once.

The thickness of the algal zone and thickness of the cortex were obtained by measurement using a x 10 eye piece with a calibrated scale together with a x 40 objective. Ten measurements were made of each feature and the average in microns was used to represent the thickness of the algal zone and thickness of the cortex.

The color of the cortex was evaluated using a mixture of reflected and transmitted light on a dissecting microscope at a magnification of x 35. Slides were examined in rapid succession and the color intensity observed was scored:

<u>Color</u>	<u>Score</u>
Hyaline	1
Orange	3
Dark brown	5

11. Quality of substrate. This feature was evaluated from material collected with the specimen. The presence of charcoal was scored 5 regardless of other materials in the substrate because specimens growing on a substrate with charcoal were in most instances markedly different

from those growing on the same substrate without charcoal. It was therefore considered necessary to regard a substrate with charcoal as distinct from the other types of substrate and, since specimens from the charcoal substrate are usually very similar in appearance to those from a mineral substrate, the two substrates were kept close together in the scoring.

<u>Substrate</u>	<u>Score</u>
Living	1
Organic	2
Organic-mineral	3
Mineral	4
Charcoal present	5

12. Moisture conditions in the immediate vicinity of specimen. This feature was evaluated from surface debris, types of mosses present and field notes.

Xeric, mesic and hydric microhabitats were recognized as points of reference. The xeric microhabitat showed little or no growth of mosses and little decay in two or three year old litter. In the mesic microhabitat mosses such as Mnium or Pylaisia were abundant; decay organisms were active and two or three year old litter unrecognizable as to origin or much altered. In the hydric microhabitat feather mosses such as Hypnum or Hylocomium flourished.

<u>Type of microhabitat</u>	<u>Score</u>
Xeric	1
Mesic	3
Hydric	5

Before the data, obtained as outlined above, were plotted the values which tended to be associated with the largest specimens and those which tended to be associated with the smallest specimens were determined. The twelve spokes of the key for constructing the polygons were then indexed

Figure 26. Key used in constructing polygonal figures of Feltigera canina features.

Details of the features and how they were evaluated are described in the text (page 74).

Some of the features in this key have their high numerical value toward the center, whereas others have the high value to the outside. This was done so that values associated with the large specimens would fall to the outside and those associated with the small specimens to the inside in order to produce polygons corresponding directly in size with the respective specimens.

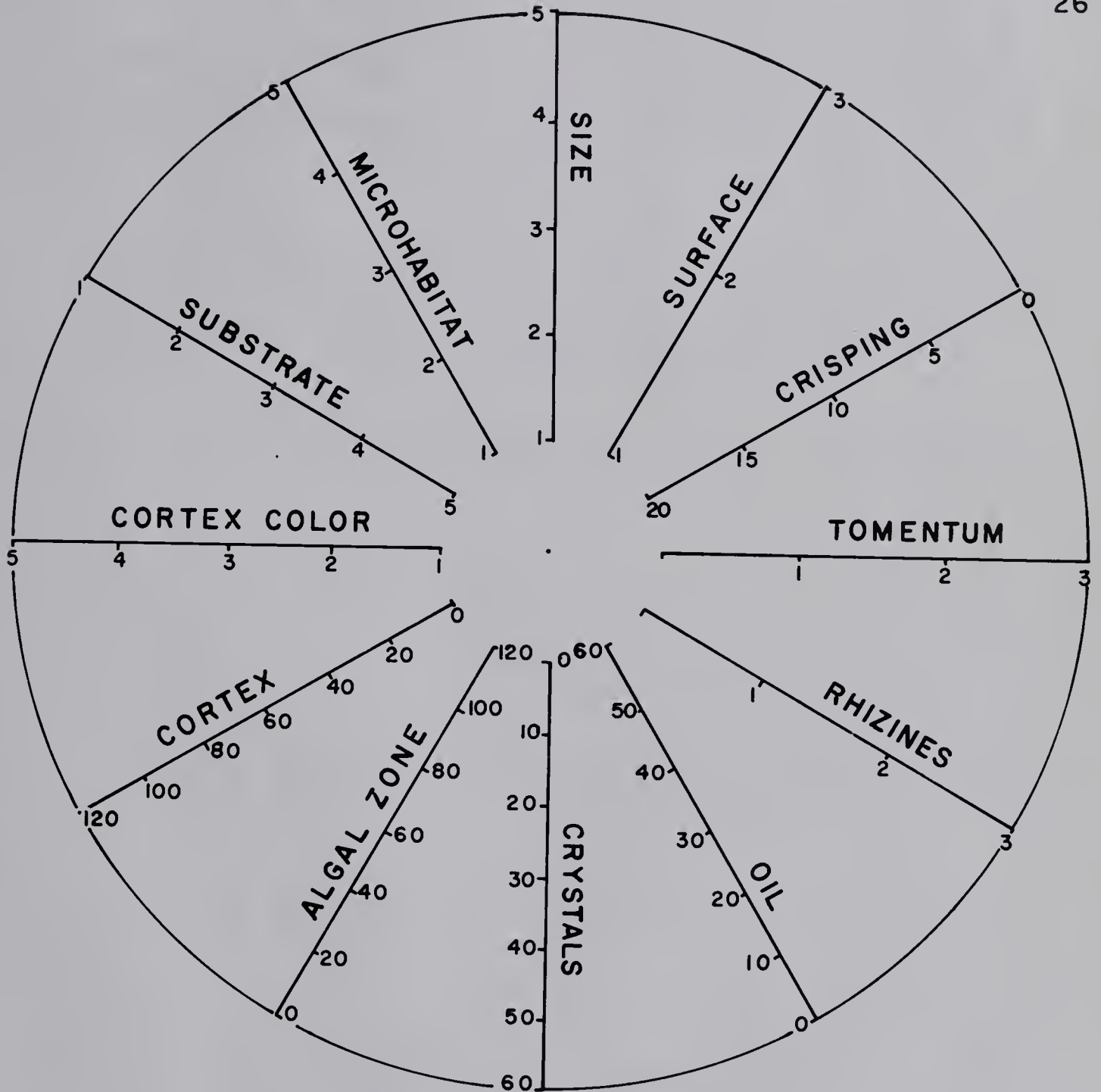


Figure 27. Key to the polygonal figures.

Figures 28-38. Polygons of features of Peltigera canina arranged in order of increasing size and microhabitat moisture.

Figures 28, 29, 30. Smallest to largest specimens recorded from microhabitat 1 (xeric).

Figures 31, 32. Smallest and largest specimens from microhabitat 2.

Figures 33, 34. Smallest and largest specimens from microhabitat 3 (mesic).

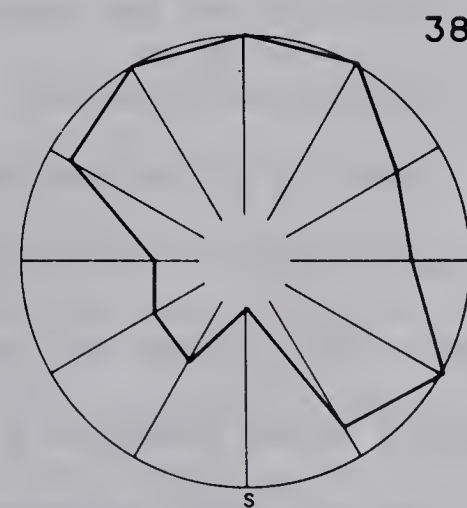
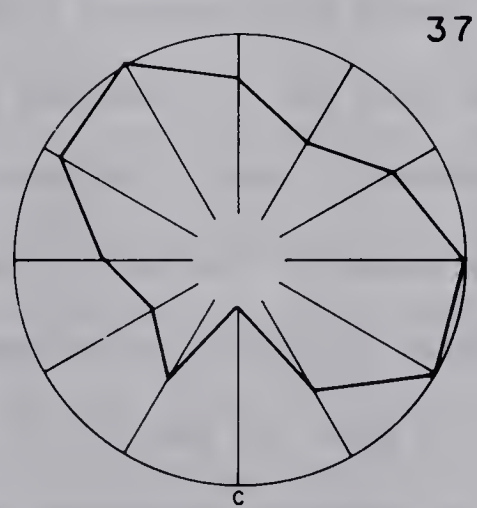
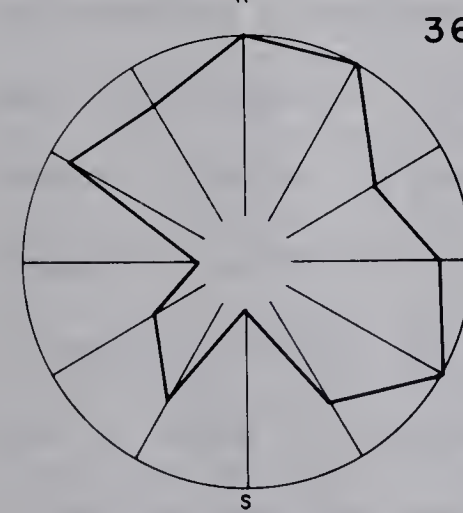
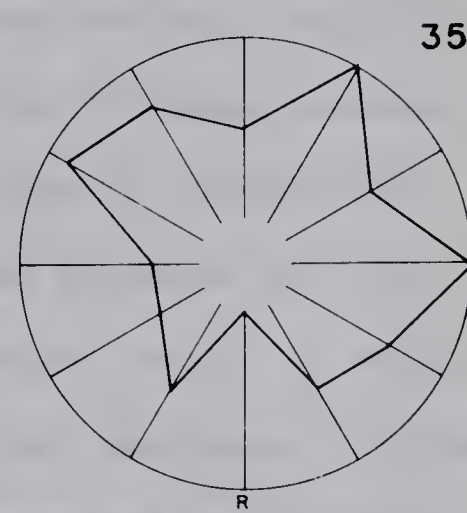
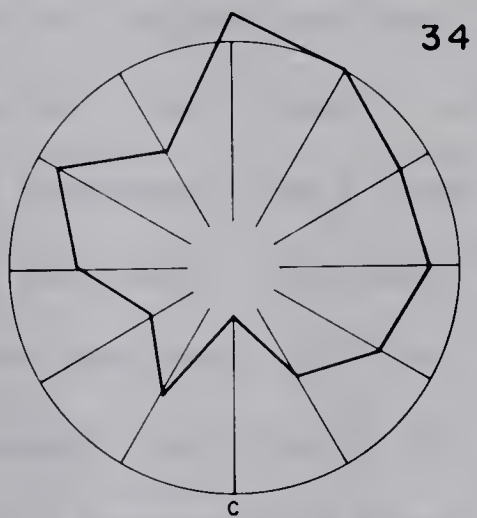
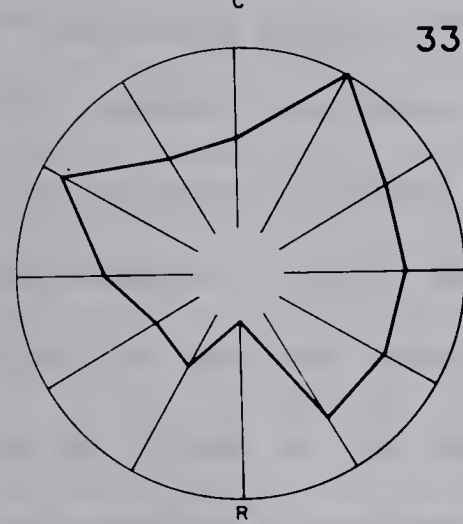
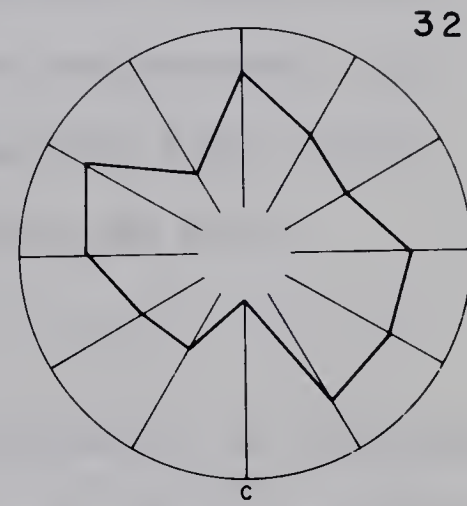
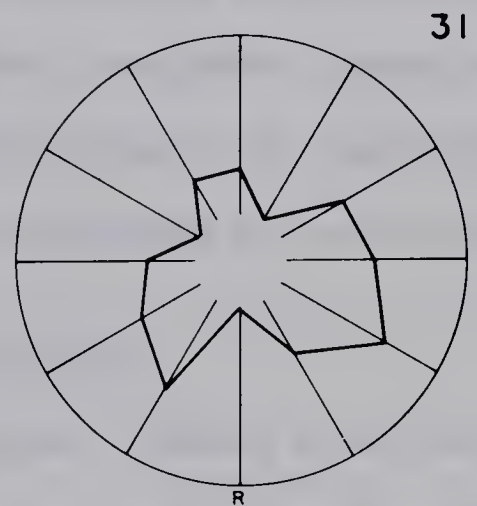
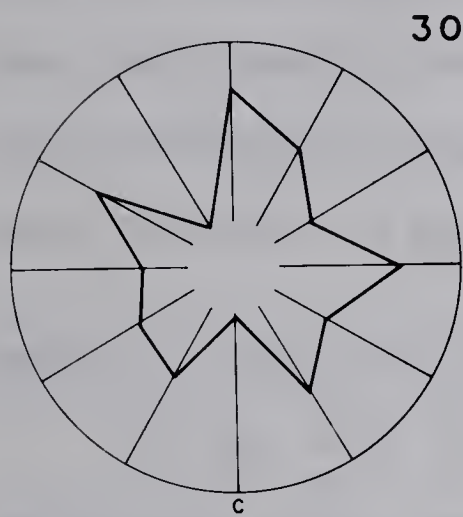
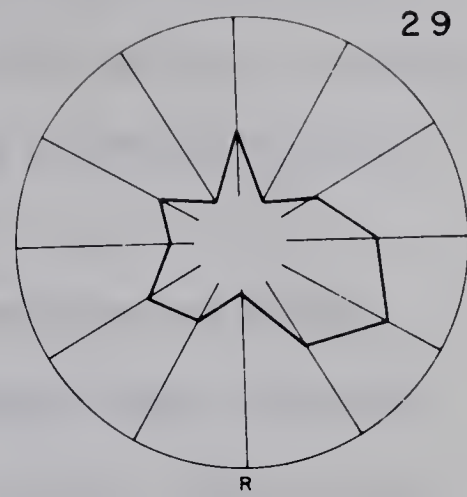
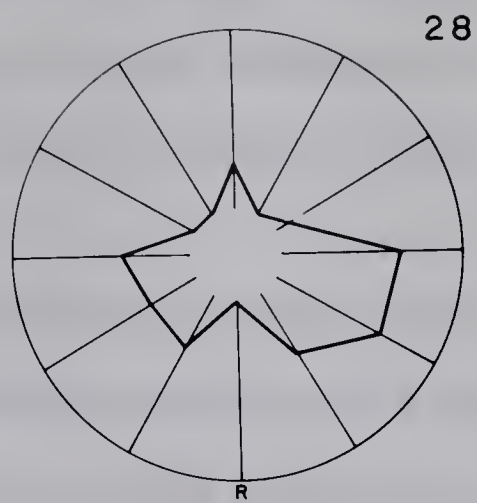
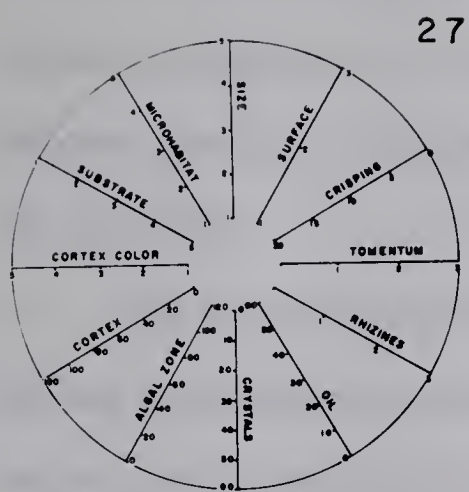
Figures 35, 36. Smallest and largest specimens from microhabitat 4.

Figures 37, 38. Smallest and largest specimens from microhabitat 5 (hydric).

The varietal identity of the specimens is indicated by the letter under the polygon.

R, rufescens; C, canina; S, spongiosa.

See page 84, paragraph 2.



in such a way that the largest polygons would be associated with the largest specimens, and the smallest polygons with the smallest specimens. The key used in constructing the polygonal figures is shown in Figure 26, page 80.

In use a sheet of tracing paper was laid over the key and the values obtained for the various features of a specimen were plotted as points corresponding with the index values on the radii. These points were then joined to produce a polygonal figure for that specimen. To aid in reading the polygonal figure the index lines were added and the whole enclosed in a circle touching the outer ends of the radii.

Analysis of selected collections.

In this study polygonal figures were constructed for 28 collections of Peltigera canina chosen to include specimens from habitats ranging from dry, exposed sand dunes to wet, cool forest. In the following presentation polygonal figures of specimens from a given type of microhabitat, for example, hydric, were selected to represent the specimens or thalli with the smallest lobes and specimens with the largest lobes. In addition to the graphs of two specimens from each of the 5 microhabitats, a polygon representing a specimen with intermediate sized lobes was included for the xeric microhabitat. This was done in the case of the xeric microhabitat because a series of specimens with small, intermediate and large lobes presents a gradation in morphological features which occurs with changes in substrate while the general microhabitat remains the same. This gradation is shown in Figures 28, 29 and 30, page 81. From these three figures it can be seen that as the substrate changes in character from charcoal to mineral to largely organic, the size of the lobes increases and the surface changes from smooth to somewhat cockled.

With the exception of the first three, the figures are paired to represent the smallest and largest lobed collections from the different microhabitats. The first five polygonal figures, those from the dry microhabitats 1 and 2, suggest a close relationship between substrate, size of the lobes and cockling of the surface. The last six, representing specimens from the more moist microhabitats 3, 4 and 5 do not show this relationship. The substrate score is the same for the last six but the size of the lobes does not remain constant. One possibility for the apparent lack of relationship between size and substrate in the more moist habitats is that the method used in evaluating this feature is not sufficiently sensitive to detect differences in the organic and living substrates. Another distinct possibility is that under dry conditions the substrate may become a controlling factor in the expression of some of the morphological features of the lichen, whereas under moist conditions substrate no longer assumes such eminence and other environmental factors play the major role in modifying the morphological features. One such environmental factor might be insolation.

An attempt was made to evaluate insolation in terms of shading of the lichen, but it was decided that this feature is so complex that it constitutes a study in itself. The values obtained for character of substrate and microhabitat contain an element which can be attributed to insolation but field observations show that direct or indirect sunlight falling on a given specimen can vary markedly from one week to the next during the growing season as the vegetation surrounding the lichen develops. Also, depending upon the location of the microhabitat occupied by a specimen, direct sunlight may not fall on it at all, it may fall on the specimen continuously for a short or a long time, or it may fall

discontinuously over short or long periods. In effect, insolation of a lichen in a particular microhabitat is a factor incorporating intensity of light, quality of light and time in a complex interrelationship. While one might speculate about the effects of light on a Peltigera thallus, factual information would require study of light reaching the specimen in its microhabitat over a period of time. A single observation in the field provides less information about insolation than can be deduced from the substrate and accompanying debris.

It should be noted here that the specimens used in this study were identified first using Thomson's keys and descriptions. These identifications were kept on file and the specimens treated as nameless entities for the analysis and plotting of polygonal figures. The names were not checked against the figures until after the series shown in Figures 28 - 38, page 81, had been set up. It can be seen that for microhabitats 1, 2, and 3, (xeric to mesic) the smaller specimens were classified as the variety rufescens and the larger specimens as the variety canina. For microhabitat 4, (intermediate between mesic and hydric), the smaller specimen was the variety rufescens, the larger was the variety spongiosa: for microhabitat 5 (hydric) the smaller specimen was the variety canina and the larger the variety spongiosa. There is here a progression in the varieties from rufescens to canina to spongiosa but it is an overlapping type of progression which emphasizes, even more than a smooth progression would, the lack of distinctive and constant features for separating the varieties rufescens, canina and spongiosa as distinct taxonomic groups. That the polygonal figures represent a natural situation and not an artificial one is suggested by the fact that not infrequently placing a particular specimen as one of the three varieties

is uncertain to say the least, and occasionally a specimen is encountered which can be placed with equal justification as the variety rufescens, canina or spongiosa. However, in my survey of Peltigera I have recognized these three varieties as well as most of the other subspecific categories which Thomson describes. The reason for doing so is that however convincing the present results may be, they are based on a relatively small number of specimens from a limited flora. It would be premature to make a major revision on such evidence.

While a good deal can be learned about a group of specimens from close examination of the individual polygons, further information can be obtained by superimposing the various polygons and determining how the values obtained for any given feature are distributed within a group of specimens. That is, do the values obtained for size, for example, range widely about a modal value, or do they have a narrow range, or do the values have more than one mode so that one might speak of a small lobed group and a large lobed group. Figure 39, page 86, will serve as an example for dealing with the distribution of values through superimposed polygonal figures.

The polygons which were superimposed are shown singly in Figures 29, 31, 36, and 38, page 81.

Considering only the feature of size of lobes in the group of four specimens selected to illustrate value distribution, it can be seen that two specimens have large sized lobes and that two have small lobes. There is no indication in this example of intermediates in size, rather, the distribution of size class values is bimodal. When similar comparisons are made for values of surface, (1:00 o'clock position); crisping (2:00); tomentum (3:00); rhizines (4:00); oil (5:00); substrate (10:00); and micro-

Figure 39. Superimposed polygonal figures for:

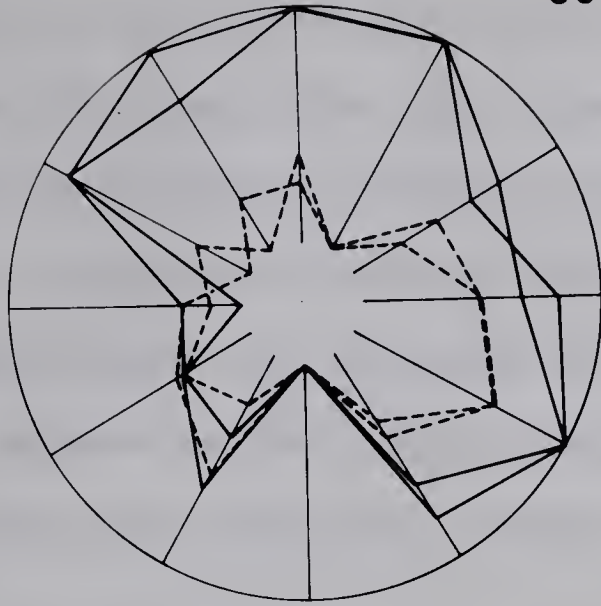
Peltigera canina var. rufescens, broken lines;

Peltigera canina var. spongiosa, solid lines.

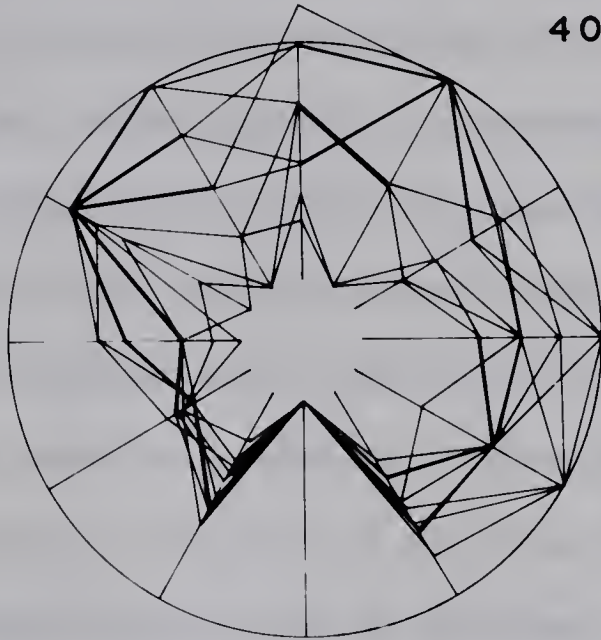
Figure 40. Superimposed polygonal figures for specimens shown in Figures 29 - 38 inclusive, page 81.

Figure 41. Superimposed polygonal figures for four specimens similar in size, microhabitat and substrate, but differing in color of cortex. Dark Brown cortex; broken lines. Orange cortex solid line. These four specimens were identified as Peltigera canina var. rufescens.

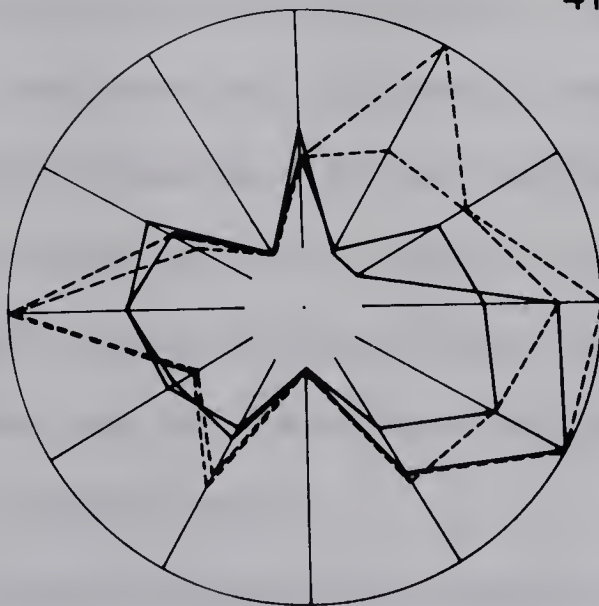
39



40



41



habitat (11:00); it can be seen that the distribution of values for these features are bimodal as is the distribution of size values (12:00). When the remaining features are compared for their value distribution it can be seen that the values for crystals (6:00) are consistently nil; that the values for algal zone thickness (7:00) are widely ranged and unimodal in their distribution; that the values for cortex thickness (8:00) are similarly unimodal in their distribution but with a narrower range; and that the values for cortex color (9:00) likewise have a unimodal distribution.

On the basis of a bimodal distribution of values in eight of the twelve features selected, there appear to be ample grounds for regarding the four specimens represented in Figure 39, page 86, as two reasonably distinct taxa. However, when the ten separate polygons shown in Figures 29 - 38, page 81, are superimposed it can be seen that the bimodal distribution of values which is evident in Figure 39, page 86, becomes non-existent. For example, size class 4 can occur in specimens from xeric to hydric microhabitats and also be associated with moderate to severe crisping. Similarly with other features, there is not a constant relationship such that one could say confidently that size class 2, severe crisping and sparse tomentum represent taxonomic group A, while size class 4, slight crisping and dense tomentum represent taxonomic group B. There are some tendencies toward these relationships among some of the features, but they are just tendencies and provide little firm ground for purposes of classification.

The polygonal graphing method offers considerable assistance in making taxonomic decisions. If one is dealing with a group of specimens which vary widely in a number of features he can see by superimposing

polygons whether the distribution of values obtained for the features is unimodal or otherwise. If the distributions are unimodal in important features, then no matter how wide ranging the distributions may be they are probably best regarded as coming from a single taxonomic group. If the distributions are bimodal then it is likely that two taxonomic groups are represented. These criteria are to be applied to an adequate sample of specimens from a complete range of habitats, because unless this is done an incomplete and possibly false picture can result. Figure 39, page 86, based only upon specimens from the driest and the wettest microhabitats is a case in point which suggests two taxonomic groups. But Figure 40, page 86, which contains representatives of the intermediate types of microhabitats in addition to those shown in Figure 39, page 86, presents a picture requiring an altogether different conclusion. That there is only one highly variable taxonomic group and that the expression of the variability is intimately linked with the environment.

In addition to providing a basis for making taxonomic decisions more objectively than is possible through direct comparisons of specimens, the polygonal figures can also be examined for suggestions pointing to possibly fruitful areas of investigation. Figure 41, page 86, might be taken as an example of that aspect.

If the four superimposed figures are examined it can be seen that the size (12:00), microhabitat (11:00), and substrate (10:00), are closely similar for the four. However, the color of the cortex (9:00) differs and apparently related to the highly colored cortex is a thinner cortex (8:00) and a thinner algal zone (7:00). Also seemingly related are the different types of surface (1:00); cockling being present with the more highly

colored cortex, and absent with the lighter cortex. There are also differences in degree of crisping (2:00), the highly colored cortex being associated with the lesser crisping. These relationships, particularly between color, cortex thickness and algal zone thickness appeared so definite in this group that some of the other polygons and specimens were reexamined to determine why this relationship broke down much of the time. A definite answer was not found but indications are that the occurrence of a pruina-like encrustation on some of the collections is very much implicated, as is also thickness of cortical cell walls. From clues arising from examination of the polygonal figures both singly and superimposed, one might be led to examine the structure and color of the cortex and any encrustation, together with thickness of cortex and algal zones as possible mechanisms in determining over-all form and adaptation of the lichen to its environment.

Summary

From the foregoing account it can be concluded that the polygonal graphing method is fully capable of dealing with mixed environmental and morphological information. Furthermore, its flexibility makes it especially useful in gaining an understanding of a group of specimens in a preliminary study. Firstly, assuming the features selected are pertinent to the problem, the polygons can be examined for taxonomic information such as revealed by distribution patterns of values obtained for the various features. Secondly, the same polygons can be examined for suggestions as to the effect of environment on a particular feature or group of features and thirdly, study of the polygons can suggest areas for detailed investigation. Another point worthy of mention is that in selecting and evaluating features one gains an appreciation of details

which are likely to escape notice in even fairly close visual comparisons.

It was not until I had attempted to describe venation numerically that it became clear that a single numerical value could not easily express all the qualities which can be observed, such as color, width and depth of veins, condition of the surface of the veins, character of the interspaces and others. In fact, it seemed that any one feature could provide enough information for constructing several polygons. From critical examination of various features came an appreciation of detail which I believe is the reason for Peltigera pulverulenta being reported for the first time for Alberta.

From my experience I can say that the polygonal graph method is a valuable tool for gaining an understanding of a group of organisms and, while it might be argued that statistical methods would be better than graphical ones, I think there is little cause for argument in stating that selecting and evaluating features is in itself sufficiently useful to an understanding to justify use of this approach. As Love and Nadeau (1961) point out, the choice between statistical and graphical methods might rest in personal preference and ability to comprehend. To some a series of numbers and regression equations can be full of meaning, while to others the same information is totally incomprehensible.

Information obtained through polygonal graph methods could serve as the basis for a monographic treatment of Peltigera, and, if adequate samples of the various taxa were analyzed, it is likely that the numbers of taxa would be reduced and that many of the subspecific categories disappear. Two species of the genus which would clearly benefit from critical examination are Peltigera horizontalis and Peltigera polydactyla,

each containing six taxa according to Thomson.

In considering any possible revision of the genus it seems likely that chemistry might play a substantial part. From my own observations it appears that there is a relationship between the occurrence of crystals and the type of venation throughout much of the genus. The species and forms with narrow veins lack materials crystallizing in GE, whereas the species with broad veins possess such materials. The presence of crystalline materials could be used in defining groups of species where venation was not clearly broad or narrow, as is the case with Peltigera pulverulenta. The relationship between crystals and venation does not hold for Peltigera apthosa, for both varieties, the veinless apthosa and the veined variolosa, yield abundant crystals. However, the occurrence of cephalodia on the upper surface of Peltigera apthosa provide a constant feature for separating this species from any other. The identity of the materials evident as crystals might provide other criteria for distinguishing species when such information is available.

Quite apart from chemistry, revision of the genus based on appropriate use of the polygonal graphing method would lead to emphasis being placed on those features which are least responsive to environmental change. This emphasis would result in simplifying identification through better definition of the species and elimination from the keys of contradictions caused by use of features whose variability is unknown. The desirability of clarifying the classification of Peltigera is made evident by the fact that, even though it is prominent in the flora, most people, including many botanists, are forced to regard the genus Peltigera as comprised of Peltigera apthosa and a vague assemblage of gray, brownish and bluish forms.

REFERENCES

- AHMADJIAN, V. 1958. A guide for the identification of algae occurring as lichen symbionts. Botan. Notiser. 111: 632-644.
- AHMADJIAN, V. 1959. Experimental observations on the algal genus Trebouxia De Puymaly. Svensk Bot. Tidskr. 53: 71-80.
- AHMADJIAN, V. 1961. Studies on lichenized fungi. Bryologist. 64: 168-179.
- ANDERSON, E. 1953. Introgressive hybridization. Biol. Rev. 28: 280-307.
- ANDERSON, E. and E.D. RUDOLPH. 1956. An analysis of variation in a variable population of *Cladonia*. Evolution. 10: 147-156.
- ASAHINA, Y. and S. SHIBATA. 1954. Chemistry of Lichen Substances. Tokyo.
- BIRD, C. D. 1966. A Catalogue of The Lichens Reported From Alberta. Department of Biology, The University of Calgary, Calgary, Alberta.
- CULBERSON, C. F. and W. L. CULBERSON. 1958. Age and chemical constituents of individuals of the lichen Lasallia papulosa. Lloydia. 21: 189-192.
- CULBERSON, W. L. 1961. Proposed changes in the International Code governing the nomenclature of lichens. Taxon. 10: 161-165.

- DARBISHIRE, O. V. 1926. The structure of Peltigera with especial reference to P. praetextata. Ann. Bot. 40: 727-758.
- DARBISHIRE, O. V. 1927. The soredia of Peltigera erumpens Wain. and P. scutata Kbr. Trans. Brit. Mycol. Soc. 12: part 1. 52-70.
- DAVIS, P. H. and V. H. HEYWOOD. 1963. Principles of Angiosperm Taxonomy. Oliver and Boyd, Edinburgh and London.
- FINK, B. 1910. The Lichens of Minnesota. Bulletin of The United States National Museum.
- FULFORD, M. 1963. Modern species concepts: liverworts. Bryologist. 66: 101-106.
- HALE, M.E. 1957. Conidial stage of the lichen fungus Buellia stillingiana and its relation to Sporidesmium folliculatum. Mycologia. 49: 417-419.
- HALE, M.E. 1961. Lichen Handbook. Smithsonian Institution, Washington, D.C.
- HALE, M. E. 1965. A Monograph of Parmelia Subgenus Amphigymnia. Contr. U.S. Nat. Herb. 36: part 5. 193-358.
- HENRIKSSON, E. 1958. Studies in the physiology of the lichen Collema. II. Svensk Bot. Tidskr. 52: 391-396.
- HENRIKSSON, E. 1964. Studies in the physiology of the lichen Collema. V. Svensk Bot. Tidskr. 58: 361-370.

- HUTCHINSON, A.H. 1936. The polygonal presentation of polyphase phenomena. Trans. Royl. Soc. Can. Ser. 3, sect. V, 30: 19-26.
- HUTCHINSON, A. H. 1940. Polygonal graphing of ecological data. Ecology. 21: 475-487.
- LAMB, I. M. 1951. On the morphology, phylogeny and taxonomy of the lichen genus Stereocaulon. Can. J. Botany. 29: 522-584.
- LAZO, W. R. and R. M. KLEIN. 1965. Some physical factors involved in actinolichen formation. Mycologia. 57: 804-808.
- LINDAHL, P. O. 1959. On the occurrence of pycnidia in the lichen genus Peltigera. Svensk Bot. Tidskr. 53: 475-478.
- LINDAHL, P. O. 1960. The different types of isidia in the lichen genus Peltigera. Svensk Bot. Tidskr. 54: 565-570.
- LÖVE, D. and L. NADEAU. 1961. The Hutchinson polygraph, a method for simultaneous expression of multiple and variable characters. Can. J. Genetics and Cytology. 3: 289-294.
- MARSLAND, D. 1957. Principles of Modern Biology. Third edition. Holt, Rinehart and Winston, Inc. New York.
- MARTIN, G. W. 1961. Nomenclature of the deuteromycetes. Taxon. 10: 153-154.
- MOSS, E. H. 1944. The prairie and associated vegetation of southwestern Alberta. Can. J. Research. 22: 11-31.

- MOSS, E. H. 1953. Forest communities in north-western Alberta. Can. J. Botany. 31: 212-252.
- QUISPEL, A. 1943. The mutual relations between algae and fungi in lichens. Rec. Trav. Bot. Neerland. 40: 413-541.
- SCOTT, G. D. 1960. Studies of the lichen symbiosis. I. New Phytol. 59: 374-381.
- SMITH, D. C. 1960a. Studies in the physiology of lichens. 1 Ann. Bot. New Series. 24: 52-62.
- SMITH, D. C. 1960b. Studies in the physiology of lichens. 2 Ann. Bot. New Series. 24: 172-185.
- SMITH, D. C. 1960c. Studies in the physiology of lichens. 3 Ann. Bot. New Series. 24: 186-199.
- THOMSON, J. W. 1948. Experiments upon the regeneration of certain species of Peltigera, and their relationship to the taxonomy of this genus. Bull. Torrey Bot. Club. 75: 486-491.
- THOMSON, J. W. 1950. The species of Peltigera of North America north of Mexico. Am. Midl. Nat. 44: 1-68.
- THOMSON, J. W. 1955. Peltigera pulverulenta (Tayl.) Nyl. takes precedence over Peltigera scabrosa T. Fr. and becomes of considerable phytogeographic interest. Bryologist. 58: 45-49.
- WEBER, W. A. 1962. Environmental modification and the taxonomy of the crustose lichens. Svensk Bot. Tidskr. 56: 293-333.

WEISZ, P.B. 1963. The Science of Biology. Second edition. McGraw-Hill Book Company, New York.

B29856